PB81-143406

Health Risks of Human Exposure to Wastewater

Cincinnati Univ. Medical Center, OH

Prepared for

Health Effects Research Lab.
Cincinnati, OH

Jan 81

U.S. Department of Commerce
National Technical Information Service
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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/1-81-002

2.

3. RECIPIENT'S ACCESSION NO. PB81 143406

4. TITLE AND SUBTITLE HEALTH RISKS OF HUMAN EXPOSURE TO WASTEWATER

5. REPORT DATE January 1981 Issuing Date.

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) C.S. Clark, C.C. Linnemann, Jr., G.L. Van Meer, G.M. Schiff, P.S. Gartside, A.B. Bjornson, E.J. Cleary, J.P. Phair, C.R. Buncher, D.L. Alexander, S.E. Trimble, & B.C. Barnett

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Departments of Environmental Health & Medicine
University of Cincinnati Medical Center
Cincinnati, OH 45267

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO. #R803643

12. SPONSORING AGENCY NAME AND ADDRESS

Health Effects Research Laboratory, Office of Research & Development, U. S. Environmental Protection Agency,
Cincinnati, OH 45268

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The primary objective of this research was to determine the health effects, if any, associated with occupational exposure to biological agents present in municipal wastewater. An additional objective was to determine the sensitivity of our methodology for detecting potential health impacts of other wastewater exposures such as recreational contact with surface water receiving wastewater effluents. The procedure was a prospective seroepidemiologic study applied to municipal wastewater workers and controls in three metropolitan areas: Cincinnati, Chicago, and Memphis. A total of over 500 volunteers participated in the study including both subjects and controls.

The protocol involved: quarterly collection of blood, throat and rectal swabs; yearly medical examinations; collection of illness information; work observations; and environmental monitoring. Final specimens in all cities were collected in the fall of 1978. The serological survey included testing for antibodies to a large group of viruses and bacteria and determination of immunoglobulin levels. Work observations were used to evaluate the level of the workers' contact with wastewater and, in conjunction with the biological air monitoring, to assess the extent of contact with aerosols. The environmental monitoring included viral and bacterial analyses of wastewater and the use of six stage Andersen samplers to determine respirable concentrations of bacteria in the work areas of the plant.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public

19. SECURITY CLASS *(This Report)* Unclassified

20. SECURITY CLASS *(This page)* Unclassified

21. NO. OF PAGES

22. PRICE

EPA Form 2220-1 (9-73)

PB81-143406

EPA-600/1-81-002
January 1981

HEALTH RISKS OF HUMAN EXPOSURE TO WASTEWATER

by

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our national environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The primary mission of the Health Effects Research Laboratory in Cincinnati (HERL) is to provide a sound health effects data base in support of the regulatory activities of the EPA. To this end, HERL conducts a research program to identify, characterize, and quantitate harmful effects of pollutants that may result from exposure to chemical, physical, or biological agents found in the environment. In addition to the valuable health information generated by these activities, new research techniques and methods are being developed that contribute to a better understanding of human biochemical and physiological functions, and how these functions are altered by low-level insults.

This report provides an assessment and discussion of data obtained on the health effects of occupational exposure to biological agents present in municipal wastewater. With a better understanding of the health effects, measures can be developed, if necessary, to reduce exposure to potentially harmful materials.

R. J. Garner
Director
Health Effects Research Laboratory

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ABSTRACT

The primary objective of this research was to determine the health effects, if any, associated with occupational exposure to biological agents present in municipal wastewater. An additional objective was to determine the sensitivity of our methodology for detecting potential health impacts of other wastewater exposures such as recreational contact with surface water receiving wastewater effluents.

The procedure was a prospective seroepidemiologic study applied to municipal wastewater workers and controls in three metropolitan areas: Cincinnati, Ohio; Chicago, Illinois; and Memphis, Tennessee. The primary study group consisted of more than 100 workers recruited at the time they began work at activated sludge plants and who remained in the study for a minimum of 12 months. In addition, in Chicago a group of 30 experienced sewage treatment plant workers were included and in Cincinnati two other wastewater-exposed groups were recruited: about 50 sewer maintenance workers and 50 primary wastewater treatment plant workers. The latter group was recruited into the study just before start-up of plant improvements that included activated sludge facilities. The purpose of including this group was to differentiate between aerosol exposure and exposure to wastewater and sludge through those operations associated with primary wastewater treatment.

The protocol has involved: quarterly collection of blood, throat, and rectal swabs; yearly medical examinations; collection of illness information; work observations; and environmental monitoring. Initial recruitment of workers began in April, 1975 in Cincinnati; July, 1976 in Chicago; and July, 1977 in Memphis. Final specimens in all cities were collected in the fall of 1978.

The serological survey included testing for antibodies to a large group of viruses and bacteria and determination of immunoglobulin levels. Work observations were used to evaluate the level of the workers' contact with wastewater and, in conjunction with the biological air monitoring, to assess the extent of contact with aerosols. The environmental monitoring included viral and bacterial analyses of wastewater and the use of six-stage Andersen samplers to determine the respirable concentrations of bacteria in the work areas of the plant.

Gastrointestinal illness rates were higher in inexperienced sewage-exposed workers with the peak occurring in the second quarter of the year.

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The study did not reveal increases in viral infections that might be related to occuptional exposure to wastewater as indicated by virus isolations in any of the cities. Evidence of viral infections indicated by distribution of antibody titers (comparative antibody levels) either in individuals or among work groups were not detected. However the few statistically significant changes in titer level are thought to represent slight evidence of increased infections among wastewater workers. Cumulative seroconversions were greater in the experienced sewage treatment plant workers in Chicago during one of the time periods examined ($p = .043$).

When level of worker exposure to wastewater and sludge or aerosols and virus antibody levels for the inexperienced wastewater-exposed workers were compared, six statistically significant differences were detected ($p \leq .05$). For five of the six, the higher exposed group had higher levels. When the inexperienced wastewater-exposed workers most exposed to wastewater and sludge or aerosols were compared to a subgroup of the control workers having the cleaner jobs, four significant differences were found between the groups with the wastewater workers higher for each. It should be pointed out, however, that 612 comparisons were performed involving wastewater workers only and 306 involving both wastewater workers and controls.

Prevalence of antibody to 17 viruses was compared to length of occupational wastewater exposure for experienced sewer maintenance and experienced sewage treatment plant workers in Cincinnati. Five of the 34 comparisons were significant at $p \leq .05$ and in four of them, workers with antibody had worked for a shorter period of time than those without antibody.

Based on the testing to date, there is no indication that occupational exposure to wastewater increased the risk of infection to Hepatitis A or B in study participants.

No evidence was found to suggest that occupational exposure to wastewater by the study participants produced any increase in bacterial infection by *Leptospira*, and *Legionella pneumophila*. There was some evidence to suggest a slight increase in infection by *Salmonella* among wastewater-exposed workers. Examination of biological specimens from workers for bacteria and parasites did not reveal any significant increase in isolation rates among sewage-exposed workers.

Immunoglobulin (IgA, IgG, IgM) levels were not found to be consistently higher in the sewage-exposed workers in any of the cities studied. Testing of liver function did not reveal any consistent abnormalities in either the sewage-exposed groups or control groups.

Airborne bacterial levels, as determined by standard plate count (SPC), inside buildings where wastewater sludge was being processed were higher than those at aeration basins. SPC levels at some highway maintenance work areas were on occasion as high as those at aeration basins of activated sludge sewage treatment plants.

In conclusion there appears to be no evidence to date to suggest that the study participants exposed to wastewater were subject to any detectable risks

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due to parasites present in wastewater. Some of the findings suggest that a slight increase in viral and bacterial infections may occur among the wastewater-exposed workers. However this conclusion must be tempered because of the preponderance of comparisons showing no apparent affect.

This report was submitted in fulfillment of Grant No. R 803643 by Health Effects Research Laboratory under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from April 7, 1975 to October 6, 1979 and work was completed as of November 25, 1980.

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ACKNOWLEDGMENTS

This study could not have been conducted without the cooperation of the more than 500 volunteers who participated in it, many of whom provided blood and other specimens as many as 14 times. The support of the organizations in which these persons were employed, their directors and staffs, is gratefully acknowledged. In Cincinnati these include the Metropolitan Sewer District of Greater Cincinnati, Mr. Richard Vanderhoof, Director, Mr. Robert Huddle, Superintendent, Mill Creek Wastewater Treatment Plant and Mr. Donald Miller, Superintendent, Division of Sewer Maintenance; and the Department of Public Works, Mr. Arthur Bird, Director and Mr. James Jester, Superintendent, Highway Maintenance Division. In Chicago study participants were employed by the Metropolitan Sanitary District of Greater Chicago, Mr. Bart Lynan, General Superintendent and Dr. Cecil Lue-Hing, Director of Research and Development; and by the Chicago Department of Water and Sewers, Mr. Richard Pavia, Director and Mr. Harry Pawlowski, Engineer of Water Purification. In Memphis the participants were employed by the Department of Public Works, Mr. Maynard Stiles, Director and Mr. Joe Taylor, and Mr. Tom Anderson, Memphis North Wastewater Treatment Plant; and the Memphis Light, Gas and Water Division, Mr. W. R. Gardiner and Mr. Bill Taylor. Space does not permit the mention of the numerous other persons in these agencies who aided the study on many occasions.

Field operations in Chicago were ably carried out by Ms. Donna McFadden, R.N. and Ms. Patricia Harlow, R.N., M.S. of our staff. Appreciation is expressed to Ms. Judy Killman, R.N. who assisted us frequently in specimen collection and to Mr. Wally David of the West-Southwest Plant staff who made arrangements for the set-up and year-round functioning of our trailer facility. Ms. Virginia Boyle, R.N. and Ms. Sandra Russell, R.N. ably staffed our operation in Memphis and Ms. Alma Walker, R.N.contributed to the Cincinnati portion of the study.

Wastewater samples from all three cities were concentrated and assayed for viruses by Dr. Lue-Hing's staff under the direction of Dr. James Bertucci. Bacterial analyses of wastewater and aerosol samples in Chicago were performed under the direction of Mr. Sam Sedita and Mr. Parnell O'Brien. Dr. David Zenz's capable support of these activities is appreciated.

Bacterial analyses of wastewater and aerosol samples in Memphis were carried out at the Memphis State University in the laboratories of Dr. George Hollis of the Department of Biology and with the cooperation of Dr. Jerry Anderson of the Department of Civil Engineering. During the latter phase of the study bacterial analyses were performed in Cincinnati in the laboratory of Dr. Pasquale Scarpino of the Department of Civil and Environmental Engineering, University of Cincinnati.

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The Cincinnati Speech and Hearing Center performed audiometric examinations in Cincinnati. Eugene Katona, Ph.D. also performed such examinations in Cincinnati and elsewhere during the study. In Memphis multiphasic and physical examinations were carried out with the support of Hal Rhea, M.D. and the Faculty Medical Practice Corporation. Appreciation is expressed to the National Institute of Occupational Safety and Health and to the Cincinnati Department of Health for use of their mobile vans for conducting multiphasic and physical examinations.

Parasitologic examinations were carried out in the Department of Microbiology at the University of Cincinnati by Ms. Judith Clark, M.S. and others. Confirmation of positive findings were made by Dr. S. Chang formerly of the U.S. Environmental Protection Agency.

Testing for antibody to Hepatitis A during the first half of the study was performed by Dr. Dan Bradley of the Hepatitis Laboratory Division of the Center for Disease Control at Phoenix, Arizona. Testing for leptospiral agglutions was performed in the Leptospirosis Reference Laboratory of the Center for Disease Control, Atlanta, Georgia.

The guidance and cooperation of Mr. Walter Jakubowski and Mr. Herb Pahren of the Health Effects Research Laboratory, Cincinnati of the U.S. Environmental Protection Agency contributed much to the successful completion of this project.

Well over 100 individuals in the above and other agencies and at the University of Cincinnati contributed to the performance of this study. Although most of them are not mentioned individually, their support of our efforts is sincerely appreciated.

Special appreciation is also expressed to my secretary, Jane Onslow, for her loyal and capable support during the entire course of this investigation.

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SECTION 1

INTRODUCTION

OBJECTIVES OF STUDY

The purpose of this study was to determine the health effects, if any, of occupational exposure to the viruses, bacteria, and parasites present in municipal wastewater. The central feature of this study was an extensive surveillance of the health of 100 newly-hired activated sludge treatment plant workers during a minimum of 12 months of occupational exposure to wastewater.

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Information regarding the human health risks associated with contact with wastewater and related materials brought about by occupational exposure, by residing near wastewater treatment plants and land application facilities, or by recreational pursuits in water receiving wastewater effluents, is limited. However, assumptions concerning these risks are providing motivation for the promulgation of state and federal standards designed to protect populations from these various exposures. The growing emphasis on the land application of wastewater and sludges as a viable method of wastes utilization increases the need for reliable and up-to-date information on the health risks, if any, involved. The focus of this study was on the biological agents in wastewater. Wastewater also contains a wide variety of harmful chemicals which may under some conditions compromise the health of wastewater workers. However, chemical hazards were not considered in this study.

The methodological tool for this assessment was a prospective epidemiological-serological study of populations that are intimately exposed to wastes by virtue of their employment as municipal sewer maintenance workers or as activated sludge wastewater treatment plant workers. Specific objectives of the project were:

1. To determine whether wastewater workers develop clinical illness or specific bacterial, viral, and parasitic infections due to occupational exposure to sewage.
2. To determine the immunologic response among workers presumed to be exposed to a high level of antigenic stimulation, i.e., through wastewaters.
3. To determine whether wastewater workers serve as a source of certain infections and, if so, whether members of the workers' families are affected.

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4. To determine the effect of exposure to aerosols generated by the activated sludge treatment process.

5. To determine the concentration of bacterial aerosols at wastewater treatment plants, and to compare them to levels at other public works facilities.

An underlying objective of the study was the determination of the sensitivity of various elements of the epidemiological-serological approach for the detection of wastewater-related health effects. Such determination would permit an assessment of the potential application of this methodology to the study of health risks associated with other population exposures to wastewaters. The latter would include persons working with or living near wastewater land-disposal facilities, persons living in the vicinity of wastewater treatment plants and persons engaged in recreational use of bodies of water receiving waste effluents.

STUDY DESIGN

The study consisted of an intensive serologic survey correlated with epidemiological, clinical, and environmental data on the study populations. The central feature of the design was an evaluation of the effects of occupational exposure to wastewater over at least a 12-month period based on the measurement of specific viral and bacterial antibodies in sera collected over that time period. In order to help separate the effect of the occupational exposure from that associated with other possible disease pathways, appropriate control groups were utilized and in addition, many of the wastewater workers were recruited into the study at the time of their initial employment in the wastewater treatment industry. Results of the serological, epidemiological, and clinical aspects of the study were associated with data from an environmental monitoring program.

Each quarter blood samples, throat swabs, and fecal samples were collected from participants in the study. Illness information was obtained by monthly health diaries maintained by the workers and their families, supplemented by telephone and on-the-job contact, generally by a project nurse. From time to time job locations of participants were visited to determine types and levels of exposure and other work conditions. Work site air was monitored periodically for bacterial concentrations, and concurrent wastewater samples at the wastewater treatment plants were analyzed for bacterial and viral concentrations. On a yearly basis study volunteers were offered a medical evaluation that included hematology, urinalysis, pulmonary function testing, blood chemistry (including tests of liver and kidney function), and examination by a physician.

As initially conceived, the study goals were limited to the first three specific objectives listed above. The population groups planned for the study were sewer and highway maintenance workers in Cincinnati, Ohio. The research design initially called for recruitment of an equal number of men beginning their respective jobs as those recruited who had two or more years experience, for both exposed and control groups. Soon after the study was

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initiated economic conditions in the municipal government forced a moratorium on hiring new employees in the Cincinnati Public Works Department which eliminated prospects for establishing a newly employed highway maintenance study group.

About one year after this research began its goals were expanded to include a determination of the health effects associated with the dispersion of aerosols generated by the activated sludge wastewater treatment process (Specific Objectives 4 and 5). At this time the study design was expanded to include two additional exposed populations groups: 50 men at the Cincinnati Mill Creek Sewage Treatment Plant which was in the process of being expanded from primary wastewater treatment to include the activated sludge process; and a total of 100 men newly employed at activated sludge treatment plants. The newly employed activated sludge treatment plant workers were recruited in Cincinnati, OH, Chicago, IL and Memphis TN. Comparison groups in the latter two cities were water treatment plant workers and gas and electric utility workers, respectively.

BACKGROUND AND LITERATURE REVIEW

Recent literature searches have revealed little evidence of occupational health problems associated with wastewater pathogens (1,2). The few situations where adverse health effects have been found were associated with sewage farming with untreated wastes or other contact with essentially raw sewage (3,4,5). A comprehensive retrospective study of Berlin sewer workers by Anders failed to yield any health problems associated with sewage pathogens (6). Residents of Israeli kibbutzim where crop irrigation with sewage is practiced, experience certain gastrointestinal disease at rates two to four times higher than people in kibbutzim not practicing such irrigation (7). From the information available in the Israel study, it was not possible to ascertain the pathway(s) of the infections. The unique nature of kibbutzim with their closely-knit living patterns complicates transferring of the kibbutzim study results to U.S. situations. More recent evaluation of the kibbutzim data has not confirmed all of the initial findings (8).

In Sweden, Rylander and his associates describe what they term a "sewage workers syndrome" in workers in a sludge drying operation producing dust mostly in the respirable size range (9). Symptoms of this syndrome include eye discharges and fever usually developing several hours after the end of the work day. Laboratory testing revealed elevated levels of the immunoglobulin IgA and of white blood cells. Their investigation has been extended to other wastewater treatment plants and these studies revealed elevated levels of immunoglobulins and increased rates of diarrhea among the exposed workers (10, 11). Layton has reported that new employees in the wastewater industry sometimes experience dysentery during the first year of employment but appear to have no unusual ill effects thereafter (12).

For a number of years one type of leptospirosis transmitted by the urine of rats infected with the bacterium Leptospira icterohaemorrhagiae (also known as Weil's disease) has been characterized as an occupational disease of sewer workers (13,14). It should be noted, however, that the Berlin study (6) and a

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more recent survey of Copenhagen sewer workers (15), failed to find evidence of an increased risk to Weil's disease in the sewer workers studied.

Based on information on cases of Hepatitis A in wastewater treatment plant workers in Ohio, Dixon and McCabe (16) concluded that wastewater treatment plant workers were at an increased risk of infection with Hepatitis A. The Copenhagen study (15) also concluded that the sewer workers had a limited risk of enteric infections such as Hepatitis A. Another finding of the Copenhagen sewer worker study (17) was that sewer workers experienced a higher than expected rate of death during the calendar year of retirement.

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SECTION 2

CONCLUSIONS

1. Gastrointestinal illness rates were higher in the experienced wastewater exposed workers than in the experienced workers and controls. Wastewater workers were not found to be subject to any detectable risks due to parasites present in wastewater. There was only slight evidence, if any, to suggest that they were subject to risks due to viruses and bacteria in wastewater.

2. Immunoglobulin levels were not found to be consistently higher in wastewater-exposed workers than in controls in any of the cities studied.

3. Wastewater workers were not found to serve as a source of viral infections for their family members.

4. In a few instances levels of antibody to certain viruses appeared to be related to level of exposure to wastewater aerosols.

5. Bacterial aerosol levels in buildings where wastewater sludge was being processed were generally higher than levels adjacent to outdoor aeration tanks at the same treatment plants. Although bacterial aerosols were generally lower at other public works facilities, levels adjacent to street cleaning activities and in indoor sewer maintenance equipment facilities were sometimes higher than at aeration tanks of wastewater treatment plants.

6. Since the seroepidemiologic approach did not detect any significant health effects of occupational exposure to wastewater it is unlikely that this approach would detect potential health impacts in populations with lower levels of exposure to wastewater.

SECTION 3

RECOMMENDATIONS

Since the basic design of this study was to compare antibody levels between two quarters in each year of the study, all sera collected over the entire study period have not been tested. It is possible that changes in antibody levels were not detected by semiannual testing. Selected viruses of high prevalence should be studied by testing all sera for each individual.

Because the predominance of seroconversions to Hepatitis B were in the sewage-exposed groups (seven of 123 sewage-exposed workers compared to one of 52 control workers), additional testing should be done of workers not yet evaluated to determine whether this trend persists.

Additional testing of sera of workers occupationally exposed to soil, such as some sewer and highway maintenance workers, would be useful in attempting to verify previous suggestions that soil exposure increases the risk of infection to Legionella pneumophila.

Because of the limited testing of sera for antibody to Hepatitis A, the initial sera of a number of workers has not been tested. It would be useful to test these sera to determine whether any of these people acquired the antibody during the course of the study.

Serologic testing for rotavirus or parvovirus agent was not performed during the study. Since these viruses are now recognized as a major cause of gastrointestinal illness, the sera collected during the study should be analyzed for antibody to them.

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SECTION 4

METHODS OF PROCEDURE

The protocol for this prospective seroepidemiological study consisted of four aspects: epidemiological, environmental monitoring, clinical, and the serological survey.

The epidemiological aspect involved selection of study population, recruitment of volunteers, collection of biological specimens four times a year for the serological and clinical survey, collection of illness, demographic, and medical history information, and worker activity observations.

The environmental monitoring aspect of the study consisted of determination of airborne bacterial levels at work site locations and assay of wastewater for viruses and bacteria.

The clinical aspect consisted of yearly multiphasic and physical examination of study volunteers, and analyses of throat and fecal specimens for bacteria, viruses and parasites. (Parasitic examinations were performed only during the early period of the study in Cincinnati.) The multiphasic and physical examinations served three purposes: (1) to evaluate whether wastewater exposure affected certain tests of liver function, (2) to assess the overall comparability of study populations, and (3) to provide motivation for volunteers to participate in the study.

The serologic survey aspect involved the determination of antibodies to a group of viruses and bacteria and measurement of immunoglobulin levels. Of concern in the serologic survey was whether the prevalence and level of antibodies were different in the wastewater exposed and control groups, and whether the number of infections as indicated by increases in antibody concentration was different among the various study groups.

A number of comparisons and correlations were made among results from the epidemiological, environmental, clinical, and serological aspects of the study.

EPIDEMIOLOGICAL ASPECTS

Selection of Study Populations

As initially conceived, the study was to include four groups of workers in Cincinnati. Each group was to be a minimum of 30 in number. Two of the groups were to be routinely exposed to municipal wastewater: one group of experienced workers with a minimum of two years exposure and the other, inexperienced

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workers just beginning such exposure. The other two groups were to be engaged in an occupation not involving wastewater contact and again, one was to have been on the job for at least two years and the other just employed. In Cincinnati, the occupational group thought to be most exposed to wastewater was sewer maintenance workers who were thus chosen as the exposed population. These workers have been maintaining the combined sanitary and storm sewer system which predates by many years the wastewater treatment plants, the larger of which were built since 1950. Highway maintenance workers of the Cincinnati Public Works Department were selected as the control group because they were similar in age, race, and socioeconomic status (SES). Office workers and engineering personnel were not recruited.

Soon after the study was initiated, economic conditions in the municipal government forced a moratorium on hiring new employees in the Cincinnati Public Works Department which eliminated prospects for establishing a newly employed highway maintenance study group and which greatly reduced the hiring of new sewer maintenance workers. To help achieve the goal of 30 inexperienced sewage-exposed workers this group was expanded to include newly-hired wastewater treatment plant workers as well as the newly-hired sewer maintenance workers. The study populations thus consisted of three groups: inexperienced sewage-exposed workers (sewer maintenance and sewage treatment plant workers), experienced sewer maintenance workers, and highway maintenance workers.

About one year after this research began, its goals were expanded to include a determination of the health effects associated with the dispersion of airborne bacteria and viruses generated by the activated sludge wastewater treatment process. The study design was then expanded to include two additional exposed populations groups: 50 men at the Cincinnati Mill Creek Sewage Treatment Plant which was in the process of being expanded from primary wastewater treatment to include the activated sludge process, and a total of 100 men newly employed at activated sludge treatment plants. Since only one-third of the 100 inexperienced activated sludge plant workers were expected to be available in Cincinnati, the study was expanded to include workers at the plants in Chicago and Memphis. These cities were chosen because at least 50 new employees would be hired within the next year, the plants contain the activated process in open basins with porous plate-type diffusers, they were reasonably accessible to Cincinnati, and the plant administrators were agreeable to the study. The Metropolitan Sanitary District of Greater Chicago (MSDGC) planned to hire a significant number of new workers because of normal work force turnover by virtue of its size. In addition, its long experience in wastewater treatment and the technical support for monitoring available from its Research and Development Department made it very suitable for study. Memphis was in the final stages of construction of its second activated sludge treatment plant, the North Treatment Plant, an entirely new facility with the workers not yet hired. In addition, its first plant, the Maxson Wastewater Treatment Plant, was hiring more workers.

In all three cities the wastewater-exposed workers recruited were generally outdoor workers engaged in various operational aspects of wastewater treatment. Again, office personnel and engineering staff were not recruited. In Chicago, the inexperienced wastewater treatment plant worker groups were laborers and security guards. For controls, laborers and selected operating

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personnel at the two Chicago water filtration plants were chosen because they were more similar in age and race to the MSDGC workers than Chicago street maintenance workers. (The choice of a control group in Chicago was also based in part on an interest in using a different occupational group than in Cincinnati where during the first year of the study the highway maintenance group repeatedly had higher IgG levels than the sewer maintenance group.) In Memphis a suitable group of workers was identified at the Gas Service Center of the Memphis Light, Gas and Water Division (MLG&W), which is a publicly owned utility.

Volunteer Recruitment

In each city meetings were held with appropriate management and employee representatives to explain the study and what was expected of participants. The study was identified as the Public Works Employees Health Study. It was stated that participation was voluntary and that all results would be treated in a confidential manner. Since participants were not to receive any direct financial payment, mention was made that the yearly medical evaluation and the availability of the services of the public health nurses employed by the study could be considered as incentives to join. Recruitment was conducted at the work place. Initial contact with potential participants just beginning employment was arranged as soon as the men reported for job orientation or personnel office processing. For experienced worker groups initial contact was through oral presentations before the assembled work forces. Potential volunteers were left with explanatory letters of invitation and with a copy of the informed consent statement. At the time of the initial contact, arrangements were made to meet with those having additional questions and/or those wanting to join.

Inexperienced sewage treatment plant workers were recruited until about 120 had joined the study in order that we could reasonably expect that after attrition, at least 100 would remain in the study for a minimum of 12 months.

To facilitate recruitment in Chicago and Memphis, two public health nurses were hired in each city on a part-time basis. In Chicago one of the nurses was eventually hired full time. A field office for the Chicago nurses was established in a rented trailer that was placed at the West-Southwest Treatment Plant. In Memphis, office space was made available for the study at the North Treatment Plant. In Cincinnati, nurses based at the University, and other staff, were responsible for volunteer recruitment.

Specimen Collection

During the quarterly collection periods, 45 ml of blood were collected from each worker, in three 15 ml red top vacutainers. After clotting at room temperature, the tubes were centrifuged, and the serum placed in labeled vials. The vials were then refrigerated at 4°C until transported to the appropriate laboratory where they were stored at -20°C until tested.

Viral isolation specimens were obtained from a throat swab collected by a medical technician or nurse, and a rectal swab collected by the participant. The collection media consisted of Eagle's Minimal Essential Medium in Earle's balanced salt solution with 1% bovine albumin, 0.15% sodium bicarbonate, 600 units penicillin/ml 600 µg streptomycin/ml and 20 µt amphotericin-B/ml. The viral specimens were kept at -20°C until transported to the appropriate laboratory on dry ice which was usually done within one week. Unless inoculated immediately, the specimens were maintained in the laboratory at -70°C.

Bacterial isolation specimens were obtained by a second rectal swab, collected by the participant at the same time as the first. The swab was inserved into Cary-Blair transport medium and the stick broken off to allow the cap to be placed on the tube. Bacterial specimens were transported at room temperature within a week to the appropriate laboratory.

During the early portion of the study, before the aerosol-exposed worker expansion, stool samples rather than rectal swabs were collected and were analyzed for parasites in addition to viruses and bacteria.

The field offices established in Chicago and Memphis facilitated collection and processing of specimens. Included in the offices were centrifuges and refrigerators with freezer chests.

During periods of illness attempts were made to collect a throat or rectal swab from the study volunteer. These specimens were generally obtained in the worker's home but on occasion were obtained at the office of his physician or at work.

Single blood specimens were obtained from the household members of study volunteers during late summer 1978. A financial incentive of $10.00 per specimen was offered. These specimens were collected for use in a limited serologic survey to look for differences among study groups in household member antibody levels.

Illness Information

Sources of illness information were: monthly family health diaries (Appendix A), telephone contacts and on-the-job contacts. The objective was to contact each worker at least once each month. At the time of worker absence telephone contact was made by a study nurse to determine if an infectious disease existed. If appropriate, a home visit was attempted for specimen collection. In order to faciliitate a worker in contacting a member of the research staff in the event of illness or to ask a question about the study, telephone answering systems consisting of tapes with remote retrieval capabilities were installed in all three cities. These systems increased communication facilities, allowing our volunteers to leave messages and call in illness information at any time of the day. The combination of methods was successful for maintaining regular contact with all participants.

Illness symptom information from all sources was combined in a manner designed to avoid double counting and was categorized as "respiratory," "gastrointestinal," and "other." The data processing procedures provided for coding various possible combinations of these. The definition of these illness categories was based on the symptoms indicated on the health diary, as follows:

Respiratory - Cold symptoms, sore throat, cough or other lower respiratory symptoms.

Gastrointestinal - Nausea, vomiting, diarrhea, or intestinal upset.

Other - Fever, persistent headache, eye inflammation or other eye trouble, earache or other ear trouble, skin infection, rash, boils, or open sores.

Demographic Information

Information collected on each worker included age, race, years of school, job classification, salary, total household income, number of persons dependent on family income, household size, and household composition broken down as to adults, school age children, and other children. The number of school age children was determined in order to evaluate their role as a source of infection.

Medical History

At the time a volunteer joined the study a family medical history questionnaire was administered by a member of the research team. Questions covered chronic health conditions and previous major health problems of household members. In addition, at the time of the annual health evaluation, a more detailed medical history questionnaire was given. Permission to share study results with the participant's personal physician was obtained at the time of recruitment.

Job Observations

Each worker was visited on his job during the study to determine type of job, frequency of wastewater contact and aerosol exposure contact, and other related work conditions. Results of these observations were used to categorize the worker on relative exposure scales for direct wastewater contact and for aerosol exposure.

ENVIRONMENTAL MONITORING

The monitoring program consisted of viral and bacterial analyses of wastewater samples and bacterial analyses of aerosols. The purpose of the aerosol sampling procedure was to provide data for estimation of the worker exposure to airborne bacteria. The viral analyses of wastewater were used in deciding what viruses to test for in the household member serologic survey. Results of viral analyses of wastewater were correlated with results of serologic testing.

Aerosol Monitoring

Six-stage Andersen samplers were used to collect the airborne bacteria (18). Each sampler was specially equipped with six molded Andersen glass petri

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dishes (Falcon 1029) containing 27 ml of plate count agar. The standard plate count (SPC) was made after incubation for 24 hours at 35 ± 0.5°C.

A replicate plate method (19) was used for determining the total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) counts on the petri dishes from the Andersen sampler. A sterile velvet cloth about 8" x 8" was used on a disc to transfer colonies from the Andersen sampler petri dishes (which should have about 50 colonies) to three other plates for determination of TC, FC and FS. For these tests the procedure was as follows:

For TC use 20 ml of ENDO agar LES and incubate at 35 ± 0.05°C for 24 hours.

For FC use 20 ml of PC agar and incubate at 44.5 ± 0.2°C for 24 hours.

For FS use 20 ml of KF streptococcal agar and incubate at 35 ± 0.5°C for 48 hours.

The velvet was sterilized for 15 minutes in fast exhaust and vacuum dried. Colonies from both wastewater samples and Andersen plates or replicas were picked and confirmed by conventional techniques.

In order to process the air samples as soon as possible, preparation and analyses of the plates for bacterial sampling were performed in Chicago by the MSDGC, in Memphis by the Memphis State University, and by the bacteriologist on the study staff in Cincinnati. At least once during the study duplicate samples were collected in Memphis and Chicago for analyses by University of Cincinnati personnel.

About 10 sites at each wastewater treatment plant were selected for airborne bacterial sampling. Locations of these sites are briefly described in the Results section.

A portable weather station was used during periods of airborne bacterial sampling. This station consisted of instruments for measuring wind direction and speed, temperature, relative humidity and barometric pressure. To conduct the aerosol sampling, the Andersen samplers were fastened to tripods about four feet high. For all aerosol samples, calibrated pumps pulling one cfm were utilized. For locations without nearby electrical outlets, the pumps were operated from automobile batteries.

Wastewater Monitoring

Bacterial--

One quart samples of primary and secondary effluent (before chlorination) were collected and analyzed for SPC, TC, FC, and FS. Methods used are described in the 14th edition of Standard Methods (20). Where a choice existed

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membrane filter techniques were used. Sampling was conducted by staff personnel and analyses were performed in each city by the same group analyzing for the bacterial aerosols.

Viral--

All wastewater samples for virus assay were collected by University of Cincinnati personnel and concentrated by the MSDGC in the Virus Laboratory at the John Egan Water Reclamation Plant. Each concentrated sample was divided into two portions, one for assay by MSDGC personnel and the other for use by study staff in Cincinnati.

Sample Collection--Twenty-four hour composite samples of six quarts, one quart collected every four hours, were gathered quarterly. Sampling locations were chosen as the effluent of the primary settling basin and the effluent of the secondary settling basins prior to chlorination in order to have samples both before and after the activated sludge process aeration tanks. In the case of the Memphis sewage treatment plant, which utilizes the contact stabilization process and does not have primary settling basins, the effluent of the grit chambers was sampled. At the West-Southwest Treatment Plant in Chicago, primary effluent samples were collected at two locations: from the primary settling tanks and from the effluent of the Imhoff tanks which are currently being used as primary settling tanks for about one-half of the incoming wastewater. Samples were collected in cubitainers previously rinsed with some of the sample. Actual sampling locations were chosen to be as representative of the plant as possible and at a point in the treatment chain before chlorine or other disinfectant was added. At the end of the collection period, all cubitainers were delivered in a chest with wet ice to the John E. Egan Water Reclamation Plant of MSDGC for processing and analysis. All samples were processed by the next day.

Virus Concentration Procedure--Samples were processed by the Aluminum Hydroxide ($Al(OH)_3$) Continuous Flow Centrifuge Technique (21). The concentration technique (see Figure 1) consisted of the addition of preformed $Al(OH)_3$ floc at the rate of 10 ml per liter of wastewater sample. The $Al(OH)_3$ was prepared immediately before addition, by adjusting 25 mM $AlCl_3+6H_2O$ to pH 7.2 with 2 M Na_2CO_3. The resulting precipitate was washed and resuspended in 0.75% NaCl. The sample was adjusted to pH 6.0 and $Al(OH)_3$ was added. Then the sample was mixed for two hours with a magnetic stirrer. The $Al(OH)_3$ and solids, each with associated viruses, were concentrated by continuous flow centrifugation (30,000 g, 5°C) employing a Sorvall KSB continuous flow system in a Sorvall refrigerated high speed centrifuge (RC5 or RC5B). The head residence time was approximately two minutes. During the continuous flow centrifugation, the sample was not stirred in order to allow large particles that would clog the KSB system to settle to the bottom while as much supernatant as possible was processed through the KSB system. The remainder of the sample was centrifuged at 9500 g in an HS-4 rotor in the refrigerated high speed centrifuge.

The sediment from both centrifugation runs was suspended in about 25-50 ml of 0.05 M glycine containing 3% disodium ethylene diamine tetraacetic acid (EDTA) and 10% HIFCS, at pH 9.0. The mixture was sonified for about

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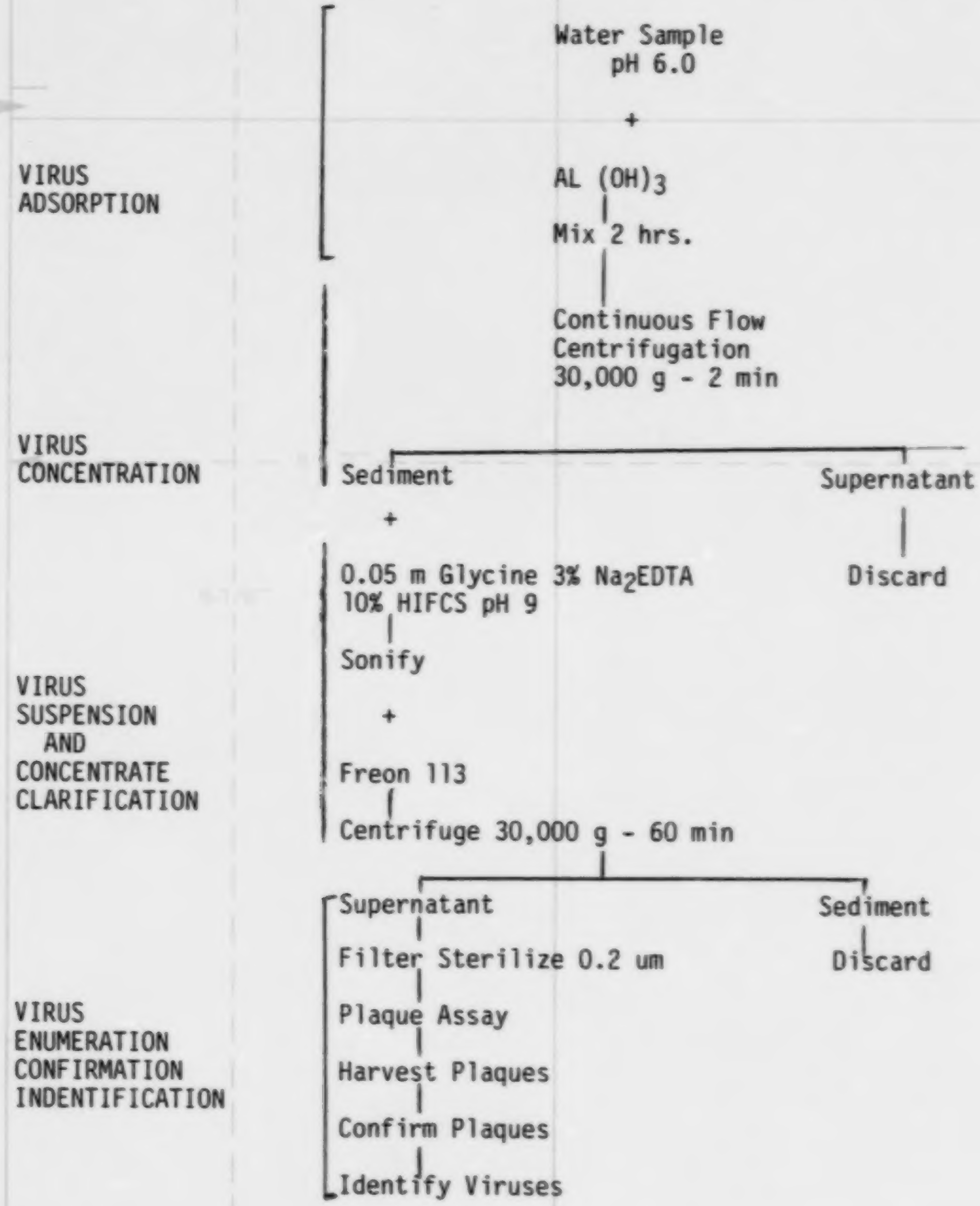

Figure 1. Abbreviated schematic for virological analysis of wastewater samples.

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60 seconds in a Branson W-350 sonifier, and then extracted with Freon-113 (DuPont). After centrifugation at 30,000 g for one hour, the supernatant was passed through a 0.2 μm polycarbonate membrane filter (Nuclepore Corp, Pleasanton, CA). The filtrate was diluted to twice its volume in HBSS containing 3% beef extract and 1% gelatin prior to storage at -70°C for virus assay. Virus concentrates were split for use by MSDGC and the University of Cincinnati.

Virus Assay--A plaque assay procedure was used by MSDGC; a tube culture method was used at the University of Cincinnati. These procedures are described below.

Cell Cultures and Media

The continuous African green monkey kidney cell line designated Buffalo Green Monkey (BGM), Rhesus primary monkey kidney (PMK), and diploid human embryonic lung (WI-38) cells were bought from Microbiological Associates, Bethesda, Maryland; Grand Island Biological Co., Grand Island, New York; and Flow Laboratories, Rockville, Maryland.

BGM and WI-38 cells were passaged on growth medium consisting of Eagle's minimum essential medium with Earle's salts (E-MEM) with 10% host inactivated fetal calf serum (HIFCS) (Reheis Chemicals, Phoenix, Arizona) and 50 μg/ml of gentamicin and 2.5 μg/ml amphotericin B or 200 iμ/ml penicillin G, 200 μg/ml streptomycin sulfate and 2.5 μg/ml of amphotericin B. They were grown in 100 mm plastic petri dishes for virus assay. The PMK cells were obtained as monolayers in 25 cm^2 flasks. Plaque assay medium consisted of E-MEM supplemented with 2% (V/V) HIFCS, nonessential amino acids, 0.05% (W/V) magnesium chloride ($MgCl_2$.$6H_2O$), 0.0017% (W/V) neutral red, 50 μg/ml gentamicin and 5 μg/ml amphotericin B and 1.5% purified agar (Difco Laboratories, Detroit, Michigan).

Virus Assay, Confirmation and Identification

One half ml volumes of sample concentrate were inoculated into 100 mm petri dish or 25 cm^2 flask monolayer cultures of cells. Following a two-hour adsorption period at room temperature, the cultures were washed with 5 to 15 ml of a Hank's balanced salt solution (HBSS) to remove sample debris prior to overlay with agar medium at 45°C. Fifteen ml and seven ml were used for petri dishes and flasks, respectively. After solidifying at reduced temperature, the plates and flasks were inverted and incubated under 5% CO_2 (V/V) at 37°C. Plates were observed daily for seven-10 days for plaque formation. During exposure to media containing neutral red, the cultures were shielded from light as much as possible.

Some concentrates were treated with poliovirus types 1, 2, and 3 antisera prior to inoculation to prevent the masking of other viruses by polioviruses. Concentrate aliquots were treated for two hours with 100 antibody units each of poliovirus 1, 2, and 3 hyperimmune antisera (Microbiological Associates, Bethesda, Maryland) to neutralize the respective viruses before inoculation into the appropriate BGM, WI-38, and PMK cell cultures.

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All plaque-like lesions observed during virus assays were scored and counted as plaques. All recognizable plaque-like lesions were picked during the seven to 10 day assay period. All plaques observed and scored during the assay were not picked if they became indistinguishable during the assay period. The plaques became indistinguishable and, therefore, were not picked when:

1. Plaques coalesced during the assay period.
2. Plaques were too close to isolate and pick
3. The culture became contaminated with bacteria or fungi, thus obscuring the plaques.

Control virus (poliovirus 1 and/or echovirus 7) diluted to approximately 50-100 PFU/ml was plaqued with each assay. Uninoculated plates were used as cell controls.

Picked plaques were placed in 2 ml E-MEM with 2% HIFCS or in EBSS with HEPES buffer as described by Fannin et al. (22), until picked plaques were inoculated into tube cultures of homologous cells for "confirmation." A plaque isolate was considered confirmed when it produced viral cytopathogenic effect (CPE) in tube culture. Confirmed isolates were identified employing neutralization tests with antisera pools.

All confirmed plaques were identified by microtiter serum neutralization tests. Twenty-five antibody units per 0.025 ml of Lim Benyesh-Melnick horse antiserum pools A through H (National Institute of Allergy and Infectious Disease, NIAID) were mixed with 100 $TCID_{50}$ per 0.025 ml of viral isolate and incubated at 37°C for two hours. A 0.05 ml amount of each virus-serum mixture was added in duplicate to wells containing 2.5 to 3.0×10^4 cells. To all wells a 0.1 ml amount of E-MEM containing 2% HIFCS and 10 ml HEPES buffer was added and plates wereincubated at 37°C in a 5% CO_2 incubator and observed daily for cytopathic effects.

Material possibly containing viruses was stored at -70°C between steps in the above procedures.

University of Cincinnati Tube Culture Assay

1. 100 antibody units of poliovirus type 1, 2, and 3 hyperimmune antisera (Microbiological Associates) were added to an equal volume of concentrated sample and incubated two hours at room temperature to neutralize poliovirus.

2. The sample was serially diluted in half-log-dilution increments through 3 $\log_{10}$.

3. 0.2 ml of each dilution was inoculated in duplicate into BGM, and HeLa roller tube cultures freshly fed with 1 ml of medium containing 2% fetal bovine serum. HeLa culture were obtained from Flow Laboratories; BGM was obtained from Microbiological Associates.

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4. Cultures were placed in stationary racks and examined for CPE on days 3, 5, 7, 10, 14, and 21.

5. If the culture sensitivity pattern and cytopathology indicated that more than one virus was involved, terminal dilution material was taken from the cultures suspected of containing different viruses and each virus purified by another terminal dilution procedure. The viruses were identified by neutralization with the Lim-Benyesh-Melnick antisera pool method.

CLINICAL ASPECTS

Annual health evaluations of study participants and viral and bacterial isolations from biological specimens were the primary sources of clinical data. Stool samples from some Cincinnati workers were examined in the early portion of the study for the presence of ova and cysts of parasites.

Multiphasic and Physical Exams

Annually each participant was provided an extensive health evaluation which included blood chemistry, hematology, urinalysis, and examination by a physician. A complete list of the tests included in these evaluations is given in Table 1.

The initial health examinations in Cincinnati were performed by the only multiphasic testing unit in Cincinnati at that time (Sycamore Professional Association) at a location a few miles from one of the work groups. Subsequent examinations in Cincinnati were conducted by University of Cincinnati Medical Center personnel, first at the Medical Center, and later at the job locations. Higher participation of volunteers in the exams occurred when they were conducted at the job site. In Chicago and Memphis, the evaluations were performed at job sites by University of Cincinnati Medical Center personnel with one exception. A portion of the first evaluation in Chicago was performed using the services of a location multiphasic mobile testing unit. but with key tests of liver and kidney function repeated in the University of Cincinnati Medical Center laboratories. Where suitable locations at the job site were not available arrangements were made to use mobile units from the National Institute of Occupational Safety and Health (NIOSH), the Cincinnati Health Department, and the Cincinnati Speech and Hearing Center.

Viral Isolation

Four cell culture types were utilized in the virus isolation procedure: Rhesus monkey kidney, Vero monkey kidney, WI-38, and HeLa. Just before inoculation the medium was discarded from the cell culture tubes. Into one tube of each of the four cell types, 0.5 ml medium and 0.3 ml specimen material was inoculated. The tubes were incubated in stationary racks at 35°C. Following overnight incubation, the initial inoculum was poured off and 2 ml of maintenance medium were added to each culture. Cultures were observed three times weekly for viral cytopathic effect (CPE). The maintenance medium was poured off and replaced with new maintenance medium on the fifth and

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TABLE 1. TESTS PERFORMED DURING MULTIPHASIC EXAMINATIONS

Coulter S. Profile

1. White Blood Cell Count (WBC)
*2. Red Blood Cell Count (RBC)
3. Hematocrit (Hct)
4. Hemoglobin (HgB)
*5. Mean Cell Volume (MCV)
6. Mean Cell Hemoglobin Concentration (MCHC)
*7. Mean Cell Hemoglobin (MCH)
*8. Platelet Observation

Blood Chemistry

*1. Total Protein
*2. Albumin
*3. Calcium
*4. Phosphorous
5. Glucose
6. Blood Urea Nitrogen (BUN)
7. Uric Acid
*8. Creatinine
*9. Total Bilirubin
*10. Alkaline Phosphatase
*11. Lactic Dehydrogenase (LDH)
*12. Serum Glutamic Oxaloacetic Transaminase (SGOT)
*13. Serum Glutamic Pyruvic Transaminase (SGPT)
*14. Trigylcerides
15. Cholesterol

Routine Urinalysis

1. Color
2. Specific Gravity
3. pH
4. Protein (Albumin)
5. Glucose
6. Ketones
*7. Bilirubin
*8. Blood
*9. Urobilinogen

NOTE: Microscopic urine examination is made if albumin or protein is detected in initial testing.

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TABLE 1 (continued)

Other Examinations

1. Audiometry
2. Pulmonary Function
3. T.B. Skin Test (PPD - Purified Protein Derivative)
4. Guaiac (hemocult slides for fecal blood)
5. Sickle Cell Preparation
6. Electrocardiography (EKG)
7. Chest X-Ray
8. Blood Pressure

*Not done in Cincinnati in 1975.

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tenth day after inoculation. Rhesus monkey kidney cultures of throat swabs were hemabsorbed with guinea pig red blood cells in order to detect the presence of hemabsorbing agents such as influenza or parainfluenza. If no CPE or hemabsorption was detected, the cultures were discarded after 14 days. In cultures where CPE was detected, preliminary identification of the virus was made by the pattern of the CPE and by the cell culture sensitivity pattern. Further identification or typing was done with specific antisera. Enteroviruses were typed with Lim-Benyesh-Melnick pools.

Bacterial Isolation

Each swab was removed from the transport medium in the laboratory and placed in tubes of Gn Broth Hajna (Difco) which inhibits gram-positive organisms and improves the recovery of *Salmonella* and *Shigella*. After incubating 18-24 hours the swabs were used to streak Eosin Methylene Blue and Hektoen Enteric Agar plates. All plates were incubated for 24 hours and inspected for possible *Salmonella* or *Shigella* colonies. Suspicious colonies were further identified by means of API enteric strips.

Parasite Isolations

Stool specimens were examined for ova and cysts of parasites in the Department of Biological Sciences of the University of Cincinnati. Stool specimens were collected by the participants. When received, they were immediately refrigerated at the job location and kept refrigerated until examined, in most cases later that same day. Specimens were examined using established methods for parasitologic analyses (23). A small portion of fresh stool was suspended in physiological saline solution and examined microscopically for helminth eggs and larvae and protozoan trophozoites and cysts. In order to facilitate detection of the eggs and cysts, a zinc-sulfate flotation technique was used for concentration of the specimen. Cover slip adherents were first examined without iodine and then a drop of Lugol's iodine was added at the edge of the cover slip and allowed to diffuse underneath.

SEROLOGICAL SURVEY

The sera collected quarterly during the study period were used for the serologic survey. The sera were analyzed for antibodies to 33 viruses or groups of viruses, 10 bacteria, and three classes of immunoglobulins, listed in Table 2. The purpose was to determine: a) whether there were differences in prevalence and levels of antibody among groups, and b) whether there were increased numbers of infections as indicated by increased antibody titers over a period of time. The relationship between increased antibody levels and the presence of illness symptoms was also evaluated. In addition. the relationship between prevalence of antibody and length of wastewater exposure were examined for experienced sewer maintenance and sewage treatment plant workers in Cincinnati.

Test Methods

Viral Serology--

Test methods used included complement fixation (CF), microneutralization

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TABLE 2. LIST OF VIRUSES, BACTERIA AND IMMUNOGLOBULINS FOR WHICH WORKERS' SERA WERE TESTED FOR ANTIBODIES

Viruses

1. Polio 1, 2, and 3
2. Coxsackie A-7, A-9, A-16, A-21, and B-1 to B-6
3. Echo 1, 3, 4, 5, 6, 8, 9, 11, 13, 14, 19, 24, and 30
4. Reovirus
5. Adenovirus
6. Cytomegalovirus
7. Herpes Simplex
8. Hepatitis A antobidy and Hepatitis B antibody and antigen

Test Methods: Microneutralization for Polio, Coxsackie and all Echo viruses; Radioimmunoassay for Hepatitis A and B; and Complement Fixation for the others.

Bacteria

1. Salmonella: Group A, B, C, D, and E
Test Methods: Rapid slide agglutination (1975-1976)
Microagglutination (1978)

2. Leptospira
Test Method: Microagglutination

3. Legionella pneumophila
Test Method: Indirect immunofluorescent

Immunologic Factors

1. IgA
2. IgG
3. IgM
4. Antiglobulin test - Latex Reaction

Test Method: Radial immunodiffusion

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(MN), and radioimmunoassay (RIA). Antibody to enteroviruses were measured by MN; Hepatitis A antibody and Hepatitis B surface antigen and antibody were measured by RIA; antibody to reovirus, adenovirus, cytomegalovirus and herpes simplex were measured by CF. Tests for antibodies to viruses were run simultaneously on at least two sera collected during different quarters for each volunteer in order to evaluate changes in titer level.

Bacterial Serology--

Initially sewer and highway maintenance workers' sera were analyzed for antibodies to Salmonella A, B, C, D, and E by rapid slide agglutination method. The method was compared with the tube dilution and passive hemagglutination techniques to see which was most sensitive. In the final year of the study, Salmonella agglutinins were measured by a standard microtiter technique. Leptospiral agglutinins were measured on two occasions by a microagglutination technique in the Leptospirosis Reference Laboratory at the Center for Disease Control. Antibody to Legionella pneumophila, was measured by indirect immunofluorescent test.

Immunoglobulins--

Antibodies are immunoglobulins which have specificity for particular antigens such as specific viruses and bacteria. Immunoglobulins are one of the body's defenses against infecting agents. Tests for these three largest classes of human immunoglobulins (Ig) were performed on sera in the study. These classes of Ig are abbreviated IgG, IgA, and IgM. IgG is the major immunoglobulin class in serum. IgA is the predominant Ig in various secretions where it defends various internal and external surfaces of the body against invasion of microorganisms. IgM antibody develops early in an infection and later decreases in concentration followed by an increase in antibodies of the IgG class. Determinations of IgA, IgG, and IgM in sera are made by radial immunodiffusion.

Sequence of Testing

Viral Serology--

Because of the large number of tests to be performed, it was necessary to begin the virus serologic testing before all of the sera were collected. For that reason the major portion of the viral serology was performed in two phases. The first phase consisted of testing Cincinnati and Chicago sera collected in quarters beginning July 1976, January 1977, and October 1977 for antibodies to the viruses listed in Table 2.

The second phase of the testing included sera from workers from all three study cities and began after the sera collection was completed. This testing was for antibodies to a more select group of viruses. Sera used were from January 1978 and October 1978 quarters plus the first sera collected from the inexperienced workers. Viruses to be tested were selected on the basis of four criteria:

(1) Prevalence during initial testing;
(2) Significant differences between groups during initial testing;
(3) Isolation from throat or rectal swabs or wastewater;
(4) Statewide prevalence according to Center for Disease Control reports and State Laboratory reports.

Testing for Hepatitis B for all wastewater exposed groups was performed on sera collected during April 1978 and October 1978. In addition first sera for all inexperienced workers were tested as were sera at least once per year prior to April 1978. Hepatitis A testing was performed by two laboratories. The Center for Disease Control Hepatitis Laboratory (Phoenix, Arizona) analyzed the first specimen and the April 1977 specimen from Cincinnati and Chicago study volunteers. The University of Cincinnati laboratory analyzed specimens collected July 1978 from all workers in the three study cities.

Bacterial Serology--

Antibodies against Legionella pneumophila were measured using sera collected during July 1978. Antibodies against Leptospira were measured using sera collected during both the July 1977 and July 1978 quarters. Salmonella testing was performed at approximately yearly intervals.

Immunoglobulins--

Serological testing for immunoglobulin levels was performed annually on sera from experienced workers and on the first two quarters for new workers and annually thereafter. The annual tests were done for all workers simultaneously and at the same time each year in order to minimize differences that may result due to seasonal variation.

Statistical Methods

In many cases the data from the serological survey were discrete in nature and did not conform to the classical normal distribution. In these cases therefore, the appropriate statistical procedures, contingency tables and chi-square tests were used. In other cases, such as for immunological and liver function data, analysis of covariance was used when the data were normally distributed or when it was possible to achieve normal distribution by log transformation of the data. Comparisons of demographic data involving participant groups as well as non-participant groups were made using the chi-square method with the Tates' correction when appropriate.

Serology--

The serological procedures used serial dilutions, and the data consisted of the highest dilution level for each worker for which antibody was found. These data comprised contingency tables, and the chi-square test was used to ascertain whether there was a significant difference in the distribution of titer levels. If a statistically significant difference existed, it was not always obvious which group had the higher average titer level. Occasionally the distributional difference could have been the result of higher and lower titers in one group and medium titers in the other. In order to facilitate interpretation of the results, the geometric mean serum titer level is given for each group. In calculating the geometric mean serum titer, titers below the starting dilultion were assumed to be one-half of the starting dilution.

In addition to the question of differences in distribution of titers between groups, the question arises as to whether there are differences between groups in titer level changes from one time period to another. Increases of four-fold or greater (two or more serum dilutions) indicate infection in individuals. Differences in titer level changes of antibody between worker groups were tested by the chi-square method.

Chi-square procedures were also used to evaluate any differences that might exist because of age, race, or exposure factors.

Immunology and Liver Function Tests--

Analysis of covariance was used with age and race as covariates for the immunology and liver function tests. The data were examined for their distributions, and where they were not normally distributed, a transform was used. In this study, in each case where a transform was needed, a log-transform was sufficient. In cases where more than two groups were compared, Scheffe' contrasts were used to find where the differences, if any, were.

SECTION 5

RESULTS AND DISCUSSION

EPIDEMIOLOGICAL ASPECTS

Recruitment of Volunteers

The initial group to be recruited was the inexperienced sewer maintenance workers in Cincinnati beginning in April 1975 followed later that year by the experienced sewer maintenance and highway maintenance workers (Table 3). When it became clear that the number of inexperienced sewer maintenance workers hired in Cincinnati would not be adequate to meet our goal of 30, a decision was made to recruit inexperienced sewage treatment plant workers as they were hired. When the study was expanded to include workers at activated sludge wastewater treatment plants, recruitment began in July 1976 at the Mill Creek Sewage Treatment Plant in Cincinnati and at plants of the Metropolitan Sanitary District of Greater Chicago. The Memphis volunteer recruitment did not begin until employees were initially hired at the Memphis North Sewage Treatment Plant in June 1977. Recruitment of inexperienced sewage treatment plant workers in all cities was allowed to continue until early 1978 to maximize the number of participants.

A total of 506 volunteers were recruited into the study. Since they were recruited into the study at various points in time from April 1975 to May 1978, the length of time they participated in the study varied widely. Three hundred thirty-six were active in the study for a minimum of 12 months. Table 4 contains a summary of volunteer recruitment by worker group and by city. Also shown are the number of workers whose sera were used in the first and second phase of the serologic surveys.

Although our protocol did not call for recruitment of experienced sewage treatment plant workers in Chicago a group of about 40 persons at the West-Southwest Plant expressed an interest in joining the study. Because these experienced workers were not part of the study protocol they were not included in the second phase of the virus serologic study.

Once in the study most workers remained active as long as they were employed. However, we were somewhat limited by a lack of continuity in some of our worker groups, particularly in Cincinnati. There was a sizable drop in the control group in December 1976 when considerable layoffs occurred in the highway maintenance department; however, this group was sufficiently large so that the number of workers remaining was adequate. Our largest rate of turnover was among the inexperienced sewage treatment workers, where there appeared to have

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TABLE 3. TIME PERIODS OF WORKER RECRUITMENT

Worker group	Time period of recruitment
Cincinnati	
Inexperienced sewer maintenance	April 1975 to April 1977
Inexperienced sewage treatment	February 1976 to May 1978
Experienced sewage treatment	July 1976 to July 1977
Experienced sewer maintenance	July 1975 to October 1976
Highway maintenance	July 1975 to October 1976
Chicago	
Inexperienced sewage treatment	July 1976 to January 1978
Experienced sewage treatment	August 1976 only
Water treatment	January 1977 to April 1978
Memphis	
Inexperienced sewage treatment	June 1977 to May 1978
Memphis Light, Gas and Water	October 1977 to February 1978

TABLE 4. NUMBER OF VOLUNTEERS RECRUITED INTO STUDY

Worker Group	Total No. Recruited	Number Who Participated Minimum of 12 Months	Number Included in First Phase of Virus Serologic Survey*	Number Included in Second Phase of Virus Serologic Survey**
Cincinnati				
Inexperienced Sewer Maintenance	12	9	7	8
Inexperienced Sewage Treatment	44	26	29	28
Experienced Sewage Treatment	54	44	41	42
Experienced Sewer Maintenance	65	50	40	40
Highway Maintenance	80	61	49	43
Subtotals	255	190	166	161
Chicago				
Inexperienced Sewage Treatment	56	38	31	45
Experienced Sewage Treatment	40	35	31	(a)
Water Treatment	50	27	23	25
Subtotals	146	100	85	70

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TABLE 4 (continued)

Worker Group	Total No. Recruited	Number Who Participated Minimum of 12 Months	Number Included in First Phase of Virus Serologic Survey*	Number Included in Second Phase of Virus Serologic Survey**
Memphis				
Inexperienced Sewage Treatment	50	27	(b)	42
Memphis Light, Gas and Water	55	19	(b)	50
Subtotals	105	46		92
Grand Total	506	336	251	323

* Sera collected July 1976, January 1977 and October 1977.

** Sera collected January 1978 and October 1978.

(a) Not included in second phase of survey.

(b) Not recruited in time for first phase of survey.

been a morale problem. This may have been due to the fact that a number of police and fire cadets were laid off from their regular jobs and were given priority for positions at the Mill Creek Sewage Treatment Plant. Many of these men left employment at the sewage plant as soon as they found work elsewhere more in line with their training.

The problem of high worker attrition did not occur in Chicago, where Metropolitan Sanitary District jobs were better paying and of somewhat higher status. In Memphis, our study participants were primarily new employees, and in the case of the Memphis North Plant, were all in a new work situation. A considerable number of these workers were laid off during their first year of employment.

For most tests the two inexperienced groups in Cincinnati were combined and called "inexperienced sewage-exposed." This was because of the small size of the inexperienced sewer maintenance group.

Routine Specimen Collection

A summary of the number of routine specimens collected from study participants is presented in Table 5. Also included is a cumulative collection efficiency which is based on the number of workers in the study during each quarter. At times of illness, rectal and throat swabs were on occasion obtained from study participants. A total of 121 such specimens were obtained, 73 from Cincinnati, 42 from Chicago, and six from Memphis.

During the summer of 1978 single blood specimens were obtained from household members of study participants. A payment of $10.00 per specimen was given. A total of 317 specimens were collected from families of 133 workers. A breakdown of these specimens by city, work group and family member is presented in Table 6.

Illness Rates

Illness information obtained from the health diaries, telephone and on-the-job contacts was compiled for the entire period of the study according to type of illness and worker group. Illness categories used are "respiratory," "gastrointestinal," "both respiratory and gastrointestinal" and "other" as defined earlier. Illness data were analyzed by two-way analyses of variance after a logistic transformation of the illness information. The logistic transform (24) was:

$$\log \quad \frac{\theta}{I-\theta}$$

where $\theta = I/W$ and I = number of illness, W = worker months of exposure. The purpose of the transform was to attempt to satisfy the assumption for analysis of variance of homogeneity of variance and normality of distribution.

Illness rates for Cincinnati participants are presented in Table 7 and those for Chicago and Memphis in Table 8.

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TABLE 5 . SUMMARY OF ROUTINE SPECIMEN COLLECTION

Work Group	Number of Specimens and Efficiency* of Collection (shown in parenthesis)		
	Blood	Throat Swabs	Rectal Swabs
Cincinnati			
Inexperienced Sewage-Exposed	282(91)	275(89)	273(88)
Experienced Sewer Maintenance	567(80)	575(81)	463(65)
Experienced Sewage Treatment	305(85)	295(82)	290(81)
Highway Maintenance	627(88)	609(86)	519(73)
Chicago			
Inexperienced Sewage Treatment	355(97)	310(84)	353(96)
Experienced Sewage Treatment	322(95)	334(99)	334(99)
Water Works	252(92)	220(80)	252(92)
Memphis			
Inexperienced Sewage Treatment	160(81)	155(78)	151(76)
Memphis Light, Gas and Water	211(97)	211(97)	211(97)

*Expressed as percent of total possible number that could have been collected.

TABLE 6. SUMMARY OF FAMILY MEMBER BLOOD COLLECTION 1978

Work Group	Number of Participants Other Adults	Children	Number of Families Involved
Cincinnati			
Inexperienced Sewage-Exposed	17	12	13
Experienced Sewer Maintenance	11	11	9
Experienced Sewage Treatment	21	18	15
Highway Maintenance	16	15	13
Chicago			
Inexperienced Sewage Treatment	15	15	14
Experienced Sewage Treatment	15	21	18
Water Works	8	13	12
Memphis			
Inexperienced Sewage Treatment	16	13	16
Memphis Light, Gas and Water	18	36	18

TABLE 7. COMPARISON OF ILLNESS RATES BETWEEN CINCINNATI WORKER GROUPS

	Illnesses/100 Worker-Months Exposure				
	Type of Illness				
Worker Group	Respiratory	Gastrointestinal	Respiratory & Gastrointestinal	Other	Total Illness
Inexperienced sewage-exposed	4.9	2.6	1.0	1.0	9.5
Experienced sewer maintenance	5.5	1.3	0.5	4.0	11.3
Experienced sewage treatment	6.5	1.6	0.9	2.0	11.0
Highway maintenance	4.7	1.6	1.1	2.7	10.1

Difference between worker groups p = .964

Difference between illness types p = .002

By 2-way ANOVA

TABLE 8. COMPARISON OF ILLNESS RATES BETWEEN WORKER GROUPS IN CHICAGO AND MEMPHIS

Worker Group	Illnesses/100 Worker-Months Exposure Type of Illness Respiratory	Gastrointestinal	Respiratory & Gastrointestinal	Other	Total Illness
Chicago					
Inexperienced sewage treatment	9.8	4.9	2.0	4.9	21.6
Control	8.5	2.4	0.9	3.7	15.5
Experienced sewage treatment	9.8	3.4	0.9	5.6	19.7
Memphis					
Inexperienced sewage treatment	2.9	2.4	2.1	5.3	12.7
Control	1.8	0.6	0.6	4.3	7.3

Difference between worker groups: Chicago, p = .064; Memphis, p = .058

Difference between illness types: Chicago, p = .0002; Memphis, p = .092

By 2-way ANOVA

There were no significant differences ($p \leq .05$) between worker groups. However, in Chicago illness rates for two exposed groups tended to be highr than those for the control group ($p = .064$), and in Memphis rates for the inexperienced exposed group were somewhat higher than for the control group ($p = .058$). Respiratory illnesses were more prevalent than the other illness types (Cincinnati $p = .002$ and Chicago $p < .001$) following patterns in the general population. In Memphis the difference between rates was not significant ($p = .092$) but rates for "other" illnesses were about twice that for respiratory illnesses.

Worker groups in all three cities were combined into inexperienced exposed, experienced exposed and controls and their illness rates were compared on a seasonal basis (Table 9). Seasonal differences were not detected for any of the illness groupings. However, for gastrointestinal illnesses the combined inexperienced exposed group had significantly higher rates ($p = .004$) than the other groups with the rate being highest in the second quarter of the year (April through June). Further analysis of illness data for the inexperienced workers was made in order to determine if this difference was related to age or length of time on the job. Workers were divided into those below or equal to the median age of the combined group, 28 years, and those above. Time of gastrointestinal illness was divided into first six months of exposure, second six months and more than 12 months. Although illness rates tended to be higher for the older workers, there were no statistically significant differences ($p \leq .05$) found either between age groups or between time periods (Table 10). Apparently the variability in the differences in rates between the two age groups was responsible for the lack of statistical significance.

A comparison of illness rates for the combined groups (Table 11) revealed a difference between illness types ($p = .023$) with respiratory illnesses being highest but not between groups ($p = .059$).

Demographic Information

Study Group Comparisons--

As study participants were recruited efforts were made to match the exposed and nonexposed workers as closely as possible for age and race. However, because of the uncontrollable factors of attrition due to employment termination and other reasons, the degree of similarity of the study groups necessarily changed throughout the time period involved. Since testing of specimens was performed during all four years of the study, various combinations of the 506 study participants were involved in the many analytical procedures. The most important combination was that used in the second phase of the virus serologic survey, and the final immunoglobulin analyses and Salmonella serologic survey. Therefore, this combination of workers was chosen for a detailed comparison of age, race, household size, years of school, and household income between groups in each city.

Differences in age and race have been detected in some of the comparisons made. For some of the data such as immunoglobulin levels and liver function tests, adjustments for these differences were made by analysis of covariance. For virus serology data, determinations of the possible effect of age and race on study results were made and are presented with the serological survey results.

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TABLE 9. SEASONAL COMPARISON OF ILLNESS RATES FOR COMBINED THREE-CITY GROUPS

	Illness/100 Worker-Months Exposure		
	Inexperienced Exposed Workers	Experienced Exposed Workers	Controls
Respiratory (with no gastro-intestinal symptoms)			
January-March	8.8	5.3	4.2
April-June	6.6	5.0	5.7
July-September	6.5	12.5	4.6
October-December	5.0	5.7	4.9
		Difference among worker groups	p = .356
		Difference among seasons	p = .642
Gastrointestinal (with no respiratory symptoms)			
January-March	3.6	1.8	1.3
April-June	5.7	2.0	1.6
July-September	2.9	2.0	1.9
October-December	2.6	1.7	1.4
		Difference among worker groups	p = .004
		Difference among seasons	p = .325
Respiratory and Gastrointestinal symptoms combined			
January-March	1.9	.5	1.8
April-June	1.0	1.4	.6
July-September	1.5	.5	.5
October-December	2.1	.4	.9
		Difference among worker groups	p = .129
		Difference among seasons	p = .791
Other			
January-March	3.8	4.5	3.5
April-June	4.6	2.7	4.5
July-September	3.9	3.9	3.0
October-December	3.1	4.1	2.5
		Difference among worker groups	p = .647
		Difference among seasons	p = .706

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TABLE 9 (continued)

	Illness/100 Worker-Months Exposure		
	Inexperienced Exposed Workers	Experienced Exposed Workers	Controls
Total Illnesses			
January-March	18.0	12.3	10.8
April-June	17.9	10.5	12.4
July-September	14.8	18.9	9.8
October-December	12.8	12.0	10.0

Difference among worker groups $p = .093$
Difference among seasons $= .641$

TABLE 10. COMPARISON OF GASTROINTESTINAL ILLNESS RATES OF COMBINED INEXPERIENCED SEWAGE-EXPOSED WORKERS ACCORDING TO LENGTH OF TIME ON JOB AND AGE (Number of Illness Episodes per 100 Worker-Months of Exposure)

	Age	
Length of time on job	≤ 28 Years	>28 Years
Less than six months	2.49	2.74
Six to 12 months	2.20	6.00
More than 12 months	3.10	3.86

Statistical analysis by two-way analysis of variance.

TABLE 11. COMPARISON OF ILLNESS RATES BETWEEN INEXPERIENCED SEWAGE-EXPOSED WORKERS AND CONTROL GROUPS*

Worker group	Illnesses/100 worker-months exposure type of illness: Respiratory	Gastrointestinal	Respiratory & Gastrointestinal	Other	Total illness
Inexperienced workers	6.5	3.6	1.7	3.9	15.7
Control workers	4.9	1.5	1.0	3.3	10.7

*Three-city combined groups.

Difference between worker groups p = .059

Difference between illness types p = .023

By 2-way ANOVA

Cincinnati--A comparison of the age distribution of the participating workers (Table 12) revealed that the inexperienced sewage exposed workers tended to be younger and the highway maintenance workers older (p<.001). Race composition of the groups differed (p<.001) (Table 13) with the experienced sewer maintenance group have a higher than average percent of black workers and the inexperienced sewage-exposed and experienced sewage plant workers having a lower than average percent of black workers. Household size did not differ between study groups (Table 14). The number of years of school completed differed (p<.001) (Table 15) with the inexperienced sewage-exposed workers (and to a lesser extent experienced sewage treatment plant workers) tending to be more educated and the experienced sewer maintenance workers less educated than average. Household income did not differ between the groups (Table 16).

Chicago--The inexperienced sewage treatment plant workers are younger as a group than the water works employees (Table 17, p = .009) and have higher household income (Table 20, p<.001). A higher percentage of water works employees were black (Table 18, p = .019). Years of school completed differed between the groups (Table 19, p = .041) with the median being 16 years lower for the controls. Household size did not differ (Table 21).

Memphis--The inexperienced worker group was younger (Table 22, p .001), had higher education levels (Table 25, p = .006), and lower household income (Table 26, p = .002) than the MLG&W workers. Race and household size did not differ (Table 23) and average household size differed slightly (Table 24).

Summary--A summary of the comparisons of demographic data in each city is presented in Table 27. The differences in age and race detected warranted that they be examined for possible influences on study results.

Participant-Nonparticipant Comparisons--

In order to determine whether the persons who volunteered to participate in the study represented a biased sample of those invited to join, comparisons were made of socioeconomic information from both groups. The variables examined included age, race, income, job classification, and years of school completed, where the information could be obtained. Job classification groupings were determined so that positions involving similar degrees of skill would be grouped together and so that adequate numbers were available for statistical comparisons. For the sewer maintenance workers in Cincinnati and for the nonexposed groups in each city these criteria resulted in the selection of job categories that were generally different for each of these four groups of workers. For Cincinnati and Memphis sewage treatment plant personnel classifications groups were operators, laborers, and other. Operators manage the various process controls at the plants and collect samples for laboratory analyses. Laborers perform a variety of unskilled duties. The other category includes tradesmen, inspectors, and the remaining workers. In Chicago the two laborer classifications and security guards are the categories used since these were the only groups recruited.

Cincinnati--

Inexperienced Sewage-Exposed. No differences in age, race, or salary were present (Table 28). For years of school completed, however, the non-

TABLE 12. COMPARISON OF AGE DISTRIBUTION BETWEEN CINCINNATI WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Age range, years	Average age in 1978, years
Inexperienced sewage-exposed	33	20-64	33.6
Experienced sewer maintenance	40	24-60	37.2
Highway maintenance	46	22-66	47.0
Experienced sewage treatment	41	22-63	38.0

p <.001 (chi-square)

TABLE 13. COMPARISON OF RACE COMPOSITION BETWEEN CINCINNATI WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

		Race (percent)	
	Size of group	Non-white	White
Inexperienced sewage exposed	29	13(45)	16(55)
Experienced sewer maintenance	40	36(90)	4(10)
Experienced sewage treatment	41	19(46)	22(54)
Highway maintenance	46	28(61)	18(39)
		96(62)	60(38)

p <.001 (chi-square)

TABLE 14. COMPARISON OF HOUSEHOLD SIZES BETWEEN CINCINNATI WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Number of households	Average size of household
Inexperienced sewage exposed	33	3.6
Experienced sewer maintenance	40	3.4
Experienced sewage treatment	45	3.7
Highway maintenance	41	4.8
		p = .790 (chi-square)

TABLE 15. COMPARISON OF YEARS OF SCHOOL COMPLETED BETWEEN CINCINNATI WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Average number of years completed
Inexperienced sewage exposed	32	12.5
Experienced sewer maintenance	40	11.1
Experienced sewage treatment	41	12.1
Highway maintenance	42	11.5
		p <.001 (chi-square)

TABLE 16. COMPARISON OF HOUSEHOLD INCOME RANGE BETWEEN CINCINNATI WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Number of Households	Median household income range ($1,000)
Inexperienced sewage exposed	29	11
Experienced sewer maintenance	40	13
Experienced sewage treatment	45	15
Highway maintenance	41	15
		p = .100 (chi-square)

TABLE 17. COMPARISON OF AGE DISTRIBUTION BETWEEN CHICAGO WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Age range, years	Average age in 1978, years
Inexperienced sewage treatment	49	19-60	38.9
Water treatment	24	28-76	50.9
			p = .009 (chi-square)

TABLE 18. COMPARISON OF RACE COMPOSITION BETWEEN CHICAGO WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Race (percent)	
	Non-white	White
Inexperienced sewage treatment	11(22)	38(78)
Water treatment	12(50)	12(50)
	23(32)	50(68)

p = .019 (chi-square)

TABLE 19. COMPARISON OF YEARS OF SCHOOL COMPLETED BETWEEN CHICAGO WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Average number of years completed
Inexperienced sewage treatment	48	12.4
Water treatment	23	10.8

p = .041 (chi-square)

TABLE 20. COMPARISON OF HOUSEHOLD INCOME RANGE BETWEEN CHICAGO WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Median household income range ($1,000)
Inexperienced sewage treatment	48	15
Water treatment	24	13

p $<$.001 (chi-square)

TABLE 21. COMPARISON OF HOUSEHOLD SIZE BETWEEN CHICAGO WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Number of households	Average size of household
Inexperienced sewage treatment	49	3.6
Water treatment	25	3.2

p = .791 (chi-square)

TABLE 22. COMPARISON OF AGE DISTRIBUTION OF MEMPHIS WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Average age, years
Inexperienced sewage treatment	43	27.4
Memphis, light, gas and water	51	37.7

$p < .001$ (chi-square)

TABLE 23. COMPARISON OF RACE COMPOSITION OF MEMPHIS WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Race (percent)	
	Non-white	White
Inexperienced sewage treatment	8(19)	35(81)
Memphis light, gas and water	20(39)	31(61)
	28(30)	66(70)

p = .033 (chi-square)

TABLE 24. COMPARISON OF HOUSEHOLD SIZE DISTRIBUTION BETWEEN MEMPHIS WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Number of households	Average size of household
Inexperienced sewage treatment	41	3.6
Memphis light, gas and water	49	3.8
		p = .025 (chi-square)

TABLE 25. COMPARISON OF NUMBER OF YEARS OF SCHOOL COMPLETED FOR MEMPHIS WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Size of group	Average number of years completed
Inexperienced sewage treatment	39	13.2
Memphis light, gas and water	47	11.0
		p = .006 (chi-square)

TABLE 26. COMPARISON OF HOUSEHOLD INCOME RANGE BETWEEN MEMPHIS WORKER GROUPS USED IN SECOND PHASE OF VIRUS SEROLOGIC SURVEY

	Number of households	Median household income range ($1,000)
Inexperienced sewage treatment	39	11
Memphis light, gas and water	45	15
		p = .002 (chi-square)

TABLE 27. SUMMARY OF STATISTICAL SIGNIFICANCE ($p < .05$) OF DEMOGRAPHIC COMPARISONS BETWEEN PARTICIPANT GROUPS IN EACH CITY

City	Age	Race	Household size	Household income	Years of school
Cincinnati	(1)	(2)	n.d.	n.d.	(3)
Chicago	(4)	(5)	n.d.	(6)	(7)
Memphis	(4)	(5)	(8)	(9)	(10)

n.d. = No significant difference.

(1) Inexperienced sewage exposed younger, control older.

(2) Inexperienced sewage-exposed and experienced sewage treatment have lower than average percent black, exposed sewer maintenance higher.

(3) Average number years school completed ranges from 11.1 for experienced sewer maintenance group to 12.5 for inexperienced sewage-exposed.

(4) Inexperienced sewage treatment group younger.

(5) Inexperienced sewage treatment group has higher percent white.

(6) Inexperienced sewage treatment group has higher average income.

(7) Average number of years completed 1.6 years higher for inexperienced sewage treatment groups.

(8) Inexperienced sewage treatment group has an average household size 0.2 persons higher than control group.

(9) Inexperienced sewage treatment group has lower average income.

(10) Inexperienced sewage treatment group has a 1.2 year higher average education.

TABLE 28. COMPARISON OF SOCIOECONOMIC DATA ON INEXPERIENCED SEWAGE-EXPOSED PARTICIPANTS AND NONPARTICIPANTS IN CINCINNATI

Age	Size of group	Age range, years	Average age, years
Participants	52	19-64	30.8
Nonparticipants	24	21-64	32.8

p = .507 (chi-square)

	Number of workers (percent)	
Race	Black	White
Participants	19(41)	27(59)
Nonparticipants	10(32)	14(58)

p = .821 (chi-square)

Years of school	Size of group	Median years of school
Participants	51	12.4
Nonparticipants	24	11.8

p = .003 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	45	10-14	11
Nonparticipants	24	10-14	10

p = .372 (chi-square)

participants on average had completed about one-half year less than the participants ($p = .003$). For comparison purposes job classifications were divided into operating personnel, laborers and others. The participants and nonparticipants did not differ (Table 29).

Experienced Sewer Maintenance Workers. A significantly lower fraction of white workers joined than black workers ($p < .001$) (Table 30). Age, years of school, job classification, and salary did not differ for the participants and nonparticipants (Tables 29 and 30).

Experienced Sewage-Treatment Plant Workers. No differences were found in age and job classification (Tables 31 and 29.). Race, years of school completed and salary differed somewhat (Table 31, $p = .026$, .047 and .040, respectively), with a higher percentage of blacks than whites joining the study and the participants having less schooling by 1.8 years and higher salary than nonparticipants.

Highway Maintenance Workers. Significant differences were found for years of school and salary (Table 32, $p = .013$ and $p = .002$), respectively, but not for age and race (Table 32). Participants tended to be somewhat more educated and higher in salary than nonparticipants. Highway maintenance job classifications were different ($p < .001$) with there being proportionately fewer laborers, tradesmen and other jobs among the participants than among nonparticipants (Table 29). This difference in jobs is consistent with the education and salary differences in that the higher education qualifies the participants for more skilled positions commanding higher salaries. The participants thus appear to have a somewhat higher SES than nonparticipants.

The differences that were found between participants and nonparticipants in Cincinnati are not thought to adversely affect the study results.

Chicago--

Inexperienced Sewage Treatment Plant Workers. There were no differences ($p \leq .05$) in age, race and years of school, between participants and nonparticipants(Table 33). However, salary levels were somewhat higher for nonparticipants (Table 33, $p = 0.025$). This was due to there being fewer Maintenance Laborer A (MLA) workers in the participant group (Table 33, $p = .040$). MLA salary scale is higher than that for MLB. About 45 percent of the available workers joined the study.

Water Treatment Plant Workers. Only information on age could be obtained for nonparticipants at the Chicago water treatment plants. There was no significant difference between the ages of the participants and nonparticipants ($p = .750$); both groups had an average age of 28.2 years.

Memphis--

Inexperienced Sewage Treatment Plant Workers. Age, race, income and job classifications were not different between participants and nonparticipants (Table 34). Information was not available for years of school completed.

TABLE 29. COMPARISON OF JOB CLASSIFICATIONS OF PARTICIPANTS AND NONPARTICIPANTS IN CINCINNATI

Inexperienced sewage-exposed workers

	Operators	Laborers	Other
Participants	15	19	11
Nonparticipants	8	15	2

p =.084 (chi-square)

Experienced sewer maintenance workers

	Operators	Laborers	Other
Participants	15	38	11
Nonparticipants	5	5	2

p = .418 (chi-square)

Experienced sewage treatment plant workers

	Operators	Laborers	Other
Participants	31	12	17
Nonparticipants	6	3	6

p = .662 (chi-square)

Highway maintenance workers

	Operators	Laborers	Tradesmen and other
Participants	28	19	22
Nonparticipants	28	54	10

p < .001 (chi-square)

TABLE 30. COMPARISON OF SOCIOECONOMIC DATA ON PARTICIPANT AND NONPARTICIPANT SEWER MAINTENANCE WORKERS IN CINCINNATI

Age	Size of group	Age range, years	Average age, years
Participants	65	24-66	40.9
Nonparticipants	12	30-63	46.7
		p = .614 (chi-square)	

Race	Number of workers (percent) Black	White
Participants	54(83)	11(17)
Nonparticipants	3(25)	9(75)
	p < .001 (chi-square)	

Years of school	Size of group	Median years of school
Participants	64	11.2
Nonparticipants	12	11.3
		p = .791 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	64	10-17	11
Nonparticipants	12	10-17	13
		p = .067 (chi-square)	

TABLE 31. COMPARISON OF SOCIOECONOMIC DATA FROM PARTICIPANT AND NONPARTICIPANT EXPERIENCED SEWAGE TREATMENT PLANT WORKERS IN CINCINNATI

Age	Size of group	Age range, years	Average age, years
Participants	58	20-63	37.8
Nonparticipants	15	20-62	35.9

p = .388 (chi-square)

Race	Number of workers (percent) Black	White
Participants	24(41)	34(59)
Nonparticipants	1(7)	14(93)

p = .026 (chi-square)

Years of school	Size of group	Median years of school
Participants	60	12.0
Nonparticipants	12	13.8

p = .047 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	57	10-25	11
Nonparticipants	15	7-14	9

p = .040 (chi-square)

TABLE 32. COMPARISON OF SOCIOECONOMIC DATA FROM PARTICIPANT AND NONPARTICIPANT HIGHWAY MAINTENANCE WORKERS IN CINCINNATI

Age	Size of group	Age range, years	Average age, years
Participants	74	22-67	43.1
Nonparticipants	86	21-64	38.7

p = .197 (chi-square)

	Number of workers (percent)	
Race	Black	White
Participants	52(71)	21(29)
Nonparticipants	59(66)	30(34)

p = .500 (chi-square)

Years of school	Size of group	Median years of school
Participants	64	11.6
Nonparticipants	86	11.0

p = .013 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	92	7-18	13
Nonparticipants	92	7-18	11

p = .002 (chi-square)

TABLE 33. COMPARISON OF SOCIOECONOMIC DATA OF INEXPERIENCED SEWAGE TREATMENT WORKERS, PARTICIPANTS AND NONPARTICIPANTS IN CHICAGO

Age	Size of group	Age range, years	Average age, years
Participants	55	19-61	38.8
Nonparticipants	68	19-62	39.8

p = .920 (chi-square)

Race	Number of workers (percent) Black	White
Participants	14(25)	40(75)
Nonparticipants	12(18)	54(82)

p = .310 (chi-square)

Years of school	Size of group	Median years of school
Participants	51	12.3
Nonparticipants	59	12.4

p = .930 (chi-square)

Job classification	MLA	MLB	Security
Participants	18	25	8
Nonparticipants	40	20	8

p = .040 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	52	14-18	15
Nonparticipants	68	14-18	17

p = .025 (chi-square)

TABLE 34. COMPARISON OF SOCIOECONOMIC DATA BETWEEN INEXPERIENCED SEWAGE TREATMENT PLANT WORKER PARTICIPANTS AND NONPARTICIPANTS IN MEMPHIS

Age (1978)	Size of group	Age range, years	Average age, years
Participants	50	19-57	27.9
Nonparticipants	30	19-57	30.6

p =.297 (chi-square)

	Number of workers (percent)	
Race	Black	White
Participants	10(20)	40(80)
Nonparticipants	5(16)	26(84)

p = .663(chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	39	5-25	11
Nonparticipants	34	6-18	11

p = .692 (chi-square)

Job classification	Operator Supervisor	Tradesmen	Laborer and other
Participants	24	8	12
Nonparticipants	25	9	6

p = .388 (chi-square)

Memphis Light, Gas and Water. Age, race, income and job classifications were not different between participants and nonparticipants (Table 35). Data on years of school was not available.

Summary--A summary of the comparisons of demographic data from participants and nonparticipants in all three cities (Table 36) revealed that for the 34 comparisons made differences ($p \leq .05$) were found for 10. No differences were found in age. The differences in income, job classification and years of school were relatively small. In the experienced sewer maintenance and sewage treatment plant groups in Cincinnati a significantly smaller percentage of white workers joined than blacks. These differences tended to make the participant experienced sewage treatment group more similar to the control group and the experienced sewer maintenance less similar than the control group. Overall these differences are not thought to affect the study results but they should be considered in their interpretation.

ENVIRONMENTAL MONITORING

Airborne Bacterial Levels

Summaries of the respirable airborne bacterial monitoring for the three cities appears in Tables 37, 38 and 39, for Cincinnati, Chicago and Memphis, respectively. Results from stages 3-6 of the Andersen sampler were used in determining the number of respirable colony forming units (5 microns diameter and smaller) per cubic meter of air (CFU/m^3). Standard Place Count (SPC) values only are shown because the values for the other parameters (TC, FC and FS) were often so low there were no differences in CFU/m^3 between sampling sites. Because results of the air monitoring were used to rank study participants into two aerosol exposure categories, SPC data were therefore more useful than data from the other measurements. In Chicago SPC levels in the sludge concentration building and near the dried sludge fertilizer preparation areas were generally much higher than that at the aeration basins. Although the Cincinnati Mill Creek Activated Sludge Plant (west side) was operating at about 20 mgd rate, compared to about 10 times that rate for each battery of basins at the Chicago West-Southwest Plant. SPC levels in the Mill Creek Plant air were as high or higher than those at the West Southwest Plant. This may be due to higher air rates and aerobic sludge digestion at the Mill Creek Plant. Airborne SPC levels at several highway maintenance locations in Cincinnati and inside the Cincinnati sewer maintenance equipment headquarters building were at times as high as those over the aeration basins at the sewage treatment plants. In all cities, airborne bacterial concentrations at the grit chambers were similar to those over the aeration tanks.

Viral Analyses of Wastewater

Forty 24-hour composite wastewater samples were collected for viral concentration and assay during the period February 1977 to October 1978. The samples ranged in volume from 4.2 to 13.2 liters. Two samples were lost because of laboratory error: primary effluent from the Chicago West-Southwest Plant 2/15/77 and secondary effluent from the Memphis North Plant 8/1/78. A complete listing of viral samples collected, date and location of collection as well as

TABLE 35. COMPARISON OF SOCIOECONOMIC DATA BETWEEN MEMPHIS LIGHT, GAS AND WATER PARTICIPANTS AND NONPARTICIPANTS

Age (1978)	Size of group	Age range, years	Average age, years
Participants	56	19-67	40.9
Nonparticipants	81	20-70	40.1

p = .850 (chi-square)

	Number of workers (percent)	
Race	Black	White
Participants	22(39)	35(61)
Nonparticipants	33(40)	49(60)

p = .840 (chi-square)

Salary	Size of group	Range ($1,000)	Median income ($1,000)
Participants	40	5-30	13
Nonparticipants	84	5-30	13

p = .140(chi-square)

Job classification	Linemen	Crew leader foremen	Other
Participants	18	11	25
Nonparticipants	23	12	30

p = .450 (chi-square)

TABLE 36. SUMMARY OF STATISTICAL SIGNIFICANCE ($p \leq .05$) OF COMPARISONS OF DEMOGRAPHIC INFORMATION FOR PARTICIPANTS AND NONPARTICIPANTS

Worker group	Age	Race	Income	Job classification	Years of school
Cincinnati					
Inexperienced sewage exposed	n.d.	n.d.	n.d.	n.d.	+
Experienced sewer maintenance	n.d.	+	n.d.	n.d.	n.d.
Experienced sewage treatment	n.d.	+	+	n.d.	+
Controls	n.d.	n.d.	+	+	+
Chicago					
Inexperienced sewage treatment	n.d.	n.d.	-	-	n.d.
Controls	n.d.	n.a.	n.a.	n.a.	n.a.
Memphis					
Inexperienced sewage treatment	n.d.	n.d.	n.d.	n.d.	n.a.
Controls	n.d.	n.d.	n.d.	n.d.	n.a.

n.d. = No difference

n.a. = No information available

+ = Participants either older, higher income, more years of school, higher percent black or more skilled job than nonparticipants ($p \leq .05$).

- = Opposite of above ($p \leq .05$).

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TABLE 37. ENVIRONMENTAL MONITORING RESULTS - CINCINNATI RESPIRABLE AIRBORNE BACTERIA, STANDARD PLATE COUNT (SPC) CFU/CUBIC METER

Location	No. Samples	Range	Geometric Mean
Mill Creek Sewage Treatment Plant			
Pump building - inside	2	87-374	180
- outside	2	32-2364	275
Administration building	2	0-35	
Grit chamber	5	19-166	43
Primary settling tanks	5	18-1106	109
Aeration tanks walkway west side	5	14-2958	217
east side	8	9-1734	109
Chemical unloading building-outside	1	388	388
Waste gas building - SW corner outside	3	31-92	60
Parking lot	3	24-798	170
Incinerator and Vacuum filter bldg. (inside)	4	19-1262	133
Service building (inside)	3	2-131	23
Thickener building (inside)	4	1313-2579	2250
Industrial waste unit	1	4	4
Sewer Maintenance			
Galbraith Headquarters			
Upper truck area	2	442-445	443
Center of shop area	2	74-770	239
Vending and lunch area	1	141	141
Haven St. - broken sewer line	1	16	16
Highway Maintenance			
Under viaduct, Gilbert yards	3	7-14	11
Colerain Ave. Headquarters			
Garage (inside)	4	7-82	20
Hallway Room 10	1	619	619
Locker room	2	24-40	31
Sign shop	2	14-54	27

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TABLE 37 (continued)

Location	No. samples	Range	Geometric mean
Salt yard - center	2	7-19	12
John Street	2	16-136	47
Fountain square	1	12	12
Ludlow Ave. near bridge (crew paving rd)	2	0	0
U.C. power plant mist	1	7	7
Street cleaner cabin - outside	1	240	240
inside	1	2002	2002

TABLE 38. ENVIRONMENTAL MONITORING RESULTS - CHICAGO RESPIRABLE AIRBORNE BACTERIA, STANDARD PLATE COUNT (SPEC) CFU/CUBIC METER

Location	No. samples	Range	Geometric mean
West Southwest Sewage Treatment Plant			
Upwind 600' from aeration tank batteries C & D	1	12	12
Western edge of MSDGC property	2	97-172	129
Aerated grit chamber - outside	1	315	315
Primary settling tanks - NW corner	2	47-640	173
Aeration tanks - center of batteries A & B	3	16-259	95
Center of batteries C & D	4	52-544	208
SE corner of battery A	2	242-574	372
NE corner battery C	1	113	113
Railroad east of batteries A & B	3	14-372	105
Final settling tank - SE corner	2	5-291	38
Sludge concentration bldg. over tanks (inside)	2	1591-2991	2181
Level 33 (sludge drying room) inside	5	402-3249	692
Vacuum filter room	1	664	664
SW corner of MSDGC property on service rd. between Imhoff tanks and sludge drying beds	1	82	82
Gate house - outside	2	120-226	165
NE corner of oxidation building	1	315	315
In front of construction building	1	179	179
Calumet Plant			
Aerated grit chamber	2	188-548	321
Aeration tanks - between batteries B & C	5	43-544	189
- E side of battery C	2	19-285	74
- NW corner battery A	1	71	71
- W of battery A	1	282	282
- E of battery B on Rd E.	3	174-906	356
- SW corner battery A	1	640	640

(continued)

TABLE 38 (continued)

Location	No. Samples	Range	Geometric mean
Calumet (continued)			
Final settling tanks - SE corner	2	2-548	33
Primary settling tanks	1	97	97
SW Corner of MSD property	3	9-212	36
Service road, SW of lagoon W of battery C	1	172	172
Entrance to machine shop by stop sign	1	268	268
Lagoon - E end on service road	1	144	144
Entrance road - 1/4 mile down	1	7	7
S. Water Works			
Intake basin	2	19-73	37
Tunnel near settling tanks	1	35	35
Between filter tables # 26-29	1	9	9
Near filter table # 62	1	5	5
Tunnel under chemical building	1	33	33
Central Filtration Plant			
NW settling basin	1	89	89
SE settling basin	1	42	42

TABLE 39. ENVIRONMENTAL MONITORING RESULTS - MEMPHIS RESPIRABLE AIRBORNE BACTERIA, STANDARD PLATE COUNT (SPC) CFU/CUBIC METER

Location		No. Samples	Range	Geometric mean
North Treatment Plant				
Service Building near first aid room (inside)		3	5-76	14
Walkway between administration bldg. & machine shop		3	32-156	90
Over grit chamber		8	92-1964	309
Blower bldg. (inside) operator area		4	25-203	70
Center of chlorine contact chamber		3	7-388	82
Aeration tanks	north end	1	597	597
	south end	1	14	14
	west side	1	403	403
	NE corner	3	67-1495	277
	center	4	180-3258	642
	SW corner	6	28-2919	233
Parking area - administration bldg.		1	103	103
Raw sewage pump station		1	292	292
Maintenance plant road - upwind		1	18	18
NE of plant - one and one half miles		1	25	25
Maxson Treatment Plant				
Grit chamber		2	139-912	356
Aeration tanks	SE corner	3	44-698	186
	center	3	148-1827	756
	NW corner	2	50-92	68
	upwind on road 50'	1	19	19
	downwind on rd. 65'	1	153	153
Chlorine contact tank building		3	35-216	71

plaque data for the three cell lines used by MSDGC is contained in Appendix B. Thirty-six confirmed viruses were isolated; three confirmed isolates could not be identified by the Lim-Benyesh Melnick Pools. Nineteen of the 36 isolates were recovered from the 19 secondary samples, the remaining 17 were from the 19 primary effluent samples. Viruses recovered were Poliovirus 1-3, Coxsackie B4 and Echoviruses 1-4, 6,7,9,13,18, and 33. A summary of the virus sampling and results by city and cell line is presented in Table 40. Most of the isolates, 28 of 36, were made using the BGM cells. The isolates with WI-38 were all from Memphis wastewater samples.

Duplicate portions of seven wastewater concentrates were analyzed at the University of Cincinnati by the tube culture procedure previously described. A comparison of these results with those obtained from the same samples by MSDGC (Table 41) indicates considerable difference in viruses recovered. Isolates from BGM cells, with prior treatment of samples with Poliovirus antisera, were Coxsackie B viruses in the tube culture method and primarily Echoviruses in the plaque assay system with one isolate not identified. The only Coxsackie A virus recovered from wastewater during the entire study was in Hela cells.

Exposure Categories

Based on the job observation data and airborne bacteria concentrations measured at various locations in the vicinity of worker activities, each worker was assigned an exposure category (Table 42). The exposure category had two components: liquid or solids contact and aerosol exposure. For each exposure type a worker was assigned to one of two exposure levels, high or low relative to other workers in the same work group and in the same city. For example, experienced sewage treatment plant workers in Cincinnati were ranked according to how their exposure compared to other experienced sewage treatment plant workers in Cincinnati. Control group workers were also ranked with respect to their fellow workers. For example, airborne bacteria levels at some highway maintenance locations in Cincinnati, those associated with street cleaning, for example, were much higher than those associated with other highway maintenance jobs. In each city some of the control workers had some contact with either contaminated water or some type of solid waste material. In Cincinnati such exposure was associated with street cleaning, in Chicago with the periodic cleaning of sludge from underground basins at the water treatment plant and in Memphis with water collected in underground chambers containing gas and electric lines. Such exposure was definitely not the same as an occupational exposure to sewage but it did allow the workers to be separated into a high or a low exposure category. In Cincinnati and Memphis the air and liquid-solids exposures for the control workers were related, workers with high exposure in the air category were also high for the liquid-solids category. In Chicago the air exposure rank was low for all control group participants.

CLINICAL ASPECTS

Multiphasic and Physical Examinations

Of most interest in the multiphasic examinations were the liver function

TABLE 40. SUMMARY OF VIRAL ISOLATES FROM WASTEWATER SAMPLES FROM CINCINNATI, CHICAGO, AND MEMPHIS WASTEWATER TREATMENT PLANTS BY CELL LINE USED

Location of samples	No. of samples	No. of isolates	Isolates			
			BGM	BGM$^+$	PMK$^+$	WI-38$^+$
Cincinnati-Mill Creek Plant						
Primary effluent	5	2	2 Poliovirus 2	--	--	--
Secondary effluent	5	0	--	--	--	--
Chicago-West-Southwest Plant						
Primary effluent	4	8	Coxsackie B4 Echovirus 7 & 18	Echovirus 4 3 Echovirus 7	Echovirus 1	--
Secondary effluent	5	6	Poliovirus 1	2 Echovirus 3 2 Echovirus 7 Echovirus 13	--	--
Chicago-Calumet Plant						
Primary effluent	4	2	2 Poliovirus 3	--	--	--
Secondary effluent	4	11	3 Poliovirus 3 Echovirus 9 & 33 1 unident.	2 Echovirus 7 Echovirus 13 Echovirus 33 1 unident.	--	--
Memphis-North Plant						
Primary effluent	4	4	--	--	--	Echovirus 2, 6, & 33, 1 unident.
Secondary effluent	3	1	--	--	--	Echovirus 2
Memphis-Maxson Plant						
Primary effluent	2	2	--	--	--	Echovirus 3 & 6
Secondary effluent	2	0	--	--	--	--
Totals	38	36	14	14	1	7

BGM: Buffalo Green Monkey; PMK: Rhesus Primary Monkey Kidney; WI-38: diploid human embryonic lung.
+: indicates treatment of sample concentrate with poliovirus antisera before inoculation into cell line.
--: no virus recovered.
unident.: unidentified enterovirus.

TABLE 41. COMPARISON OF VIRUS ISOLATES FROM CHICAGO WASTEWATER CONCENTRATES ANALYZED BY DIFFERENT PROCEDURES

		Isolates					
		Tube cell culture		Plaque assay			
Sample source	Date collected	BGM$^+$	HeLa$^+$	BGM	BGM$^+$	PMK$^+$	WI-38$^+$
West-Southwest							
Secondary effluent	2/16/77	--	--	--	--	--	--
Calumet							
Primary effluent	2/18/77	--	Coxsackie A15	Poliovirus 3	--	--	--
Secondary effluent	2/18/77	--	--	--	Echovirus 13 and 33	--	--
West-Southwest							
Primary effluent	6/20/77	Coxsackie B1	--	Echovirus 18	Echovirus 4	--	--
Secondary effluent	6/20/77	--	Coxsackie B5	--	2 Echovirus 3 Echovirus 13	--	--
Calumet							
Primary effluent	6/23/77	Coxsackie B1 and B3	--	Poliovirus 3	--	--	--
Secondary effluent	6/23/77	Coxsackie B1 and B3	--	3 Poliovirus 3 Echovirus 9 and 13 1 unident.	1 unident.	--	--

BGM: Buffalo Green Monkey; PMK: Phesus Primary Monkey Kidney; WI-38: diploid human embryonic lung.
+: indicates concentrate treated with poliovirus antisera before inoculation.
--: no virus recovered.
unident.: unidentified enterovirus.

TABLE 42. EXPOSURE RANKINGS FOR WORKERS INCLUDED IN FINAL VIRUS SEROLOGY SURVEY

	Number of Workers			
Work Group	High aerosol and high liquid-solids	Low aerosol and high liquid-solids	High aerosol and low liquid-solids	Low aerosol and low liquid-solids
Cincinnati				
Inexperienced Sewer Maintenance	0	5	0	4
Inexperienced Sewage Treatment	7	3	5	11
Experienced Sewage Treatment	5	11	7	20
Experienced Sewer Maintenance	0	26	0	19
Highway Maintenance*	22	0	0	26
	34	45	12	80
Chicago				
Inexperienced Sewage Treatment	18	6	5	20
Water Works*	0	8	0	24
	18	14	5	44
Memphis				
Inexperienced Sewage Treatment	18	13	5	6
Memphis Light, Gas and Water*	25	0	0	25
	43	13	5	31

* For these groups the exposures were not to wastewater and wastewater aerosols as such. Ranking of these workers was for the purpose of separating those workers who had dirtier work environments than the rest of the workers in their respective groups.

tests since infections with several of the enteroviruses can affect the liver. Results from these tests (SGOT, SGPT, albumin, alkaline phosphatase, and total bilirubin) from all three cities are given in Table 43. SGPT was determined in Cincinnati in 1977 and 1978, in Chicago in 1978, and in Memphis in 1977 and 1978. The other tests were performed on Cincinnati workers in 1976-1978, but not in 1975, so are given for three years for those workers and two years for the Chicago and Memphis workers.

A summary of statistically significant results ($p \leq .05$) is given in Table 44 for all multiphasic examinations, including the SMA-12, urinalysis, hematology, (See Table 1 for list). Although a number of results are significant, these results are not consistent from year to year. In only one case is a test result significant in more than one year in the same city; MCHC in Cincinnati for 1976 and 1977. However, this result does not continue into 1978. In only one case is the same test result significant in more than one city for the same year, MCH in Cincinnati and Memphis in 1977. This result does not appear in either city in any other year or in Chicago at any time. Glucose and calcium test results are significant in both Cincinnati (1976) and Memphis (1977 and 1978, respectively), but not in the same year. In Cincinnati 1976 glucose is higher in the controls than in the experienced groups; in Memphis 1977 it is lower in the controls. In both cities the significant results for calcium show the controls higher, but the results are two years apart.

The multiphasic examinations, therefore, have not indicated any consistent differences among worker groups in any city. The differences which were found are not clinically significant.

Tuberculosis Skin Testing--One of the tests performed in the multiphasic examination was the tuberculosis skin test. This test requires a reading by a trained person 48 hours after it is administered. In situations where such a reading was not made the result is called "unknown." In addition, in cases where a worker thought he previously tested positive in another survey and we could not confirm the previous result, the designation "unknown" was also used. Because a severe reaction can develop if a retest is given to a person previously tested positive, a policy against such retesting was established. Application of these stringent conditions resulted in there being sufficient data for comparison only in Cincinnati. An overall summary of the results for Cincinnati participants and the age and race of the population tested are shown in Table 45. Age was found to be a significant covariable ($p = .0001$, Table 46). However, because the nonwhite population tended to be older, the results by race when adjusted for age were not significant ($p = .136$). There was a significant difference by group ($p = .018$) when adjusted for age and race with experienced sewer maintenance and highway maintenance having more positive values.

Medical Evaluation--The results of annual clinical histories, physical examinations, and laboratory tests were evaluated for all worker groups by city and by year. There was no evidence of significant clinical differences in health status among the groups. Noninfectious and infectious diseases were evaluated and there were no differences in skin, musculoskeletal, cardiovascular, respiratory, gastrointestinal, genitourinary tract, or neurological

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TABLE 43. MULTIPHASIC EXAMINATIONS - LIVER FUNCTION TEST RESULTS

ISE = Experienced Sewage-Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Workers
HW = Highway Maintenance Workers
WT = Water Treatment Workers

Test	Mean Values				Difference Among Groups	Significance of Age	Race
	ISE	ESM	EST	HM			
Cincinnati - 1976							
Number of workers	24	54	42	67			
SGOT*	25.5	32.5	23.6	25.5	.021	.164	.148
Albumin	4.72	4.68	4.72	4.63	.432	.001	.060
Alkaline Phosphatase*	73.0	65.4	68.0	70.1	.092	.816	.100
Total Bilirubin*	.68	.61	.54	.62	.139	.427	.011
1977:							
Number of workers	29	35	40	41			
SGOT*	27.1	35.2	26.6	26.6	.088	.952	.003
SGPT*	27.9	18.2	17.5	20.5	.943	.119	.991
Albumin	4.72	4.69	4.66	4.76	.642	<.001	.563
Alkaline Phosphatase*	75.9	74.4	73.7	68.0	.046	.304	.137
Total Bilirubin*	.62	.70	.62	.58	.113	.006	.006
1978:							
Number of workers	30	36	38	38			
SGOT*	23.3	30.3	23.8	27.7	.328	.755	.045
SGPT*	21.1	20.3	19.5	20.3	.530	.185	.202
Albumin	4.77	4.69	4.70	4.69	.503	.001	.113
Alkaline Phosphatase*	70.8	73.7	73.7	68.0	.524	.701	.308
Total Bilirubin*	.44	.47	.43	.44	.503	.936	.092
Chicago - 1977	ISE	EST	WT				
Number of workers	43	38	39				
SGOT*	28.2	23.8	26.0		.509	.217	.893
Albumin	4.6	4.4	4.3		.005	.011	.647
Alkaline Phosphatase*	60.9	68.7	78.3		.141	.519	.271
Total Bilirubin*	0.7	0.7	0.5		.070	.443	.075
1978:							
Number of workers	24	27	16				
SGOT*	29.1	27.1	24.0		.022	.557	.933
SGPT*	13.9	13.7	12.1		.221	.667	.607
Albumin	4.6	4.4	4.4		.882	.046	.271
Alkaline Phosphatase*	73.7	71.5	64.7		.090	.596	.068
Total Bilirubin*	.58	.59	.69		.070	.112	.299

*Geometric Mean

(continued)

TABLE 43 (continued)

ISE = Inexperienced Sewage-Exposed Workers
MLGW = Memphis Lignt, Gas and Water Workers

	Mean Values		Difference Among Groups	Significance of	
	ISE	MLGW		Age	Race
Memphis - 1977					
Number of workers	28	49			
SGOT*	27.1	24.3	.136	.496	.382
SGPT*	15.0	12.1	.086	.605	.981
Albumin	4.88	4.78	.893	.018	.294
Alkaline Phosphatase*	67.4	66.0	.567	.327	.857
Total Bilirubin*	.51	.50	.761	.590	.267
1978:					
Number of workers	35	41			
SGOT*	19.1	17.5	.762	.078	.212
SGPT*	18.0	13.7	.152	.227	.477
Albumin	4.80	4.59	.207	.081	.003
Alkaline Phosphatase*	71.5	61.6	.142	.575	.681
Total Bilirubin*	.61	.48	.041	.862	.977

* Geometric Mean

Normal Range

SGOT	10-40 mU/ml (8-22 mU/ml for 1978)
Albumin	3.5-5.0 mg%
Alkaline Phosphatase	50-90 mU/ml (32-72 mU/ml for 1978)
Total Bilirubin	0.1-1.0 mg/dl
SGPT	5-25 mU/ml

TABLE 44. MULTIPHASIC EXAMINATION - SUMMARY OF SIGNIFICANT RESULTS ($p \leq .05$)

ISE = Inexperienced Sewage-Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Workers
HM = Highway Maintenance Workers
WT = Water Treatment Workers
MLGW = Memphis Light, Gas and Water Workers

Test	p (Adjusted for age and race)	ISE	ESM	EST	HM
Cincinnati - 1975: None					
1976:					
Number of workers		24	54	42	67
SGOT* 10-40 mU/ml**	.021	25.5	32.5	23.6	25.5
Glucose* (Blood) 65-100 mg/dl	.005	75.2	95.6	83.1	91.8
Calcium (Blood) 8.5-10.5 mg/dl	.025	9.9	9.8	10.1	10.1
Total Protein* (Blood) 6.0-8.0 g/dl	.001	7.5	7.7	7.3	7.8
HCT* 42.0-50.0%	.015	42.9	43.8	43.8	44.7
MCHC 33.0-38.0%	.001	34.1	33.7	34.3	33.5
Triglycerides 30-135 mg/dl	.023	113.3	156.0	106.7	112.2
1977:					
Number of workers		29	35	40	41
Alkaline Phosphatase* 50-90 mU/ml	.046	75.9	74.4	68.0	73.7
MCH 27.0-31.0 μμg	.036	30.6	27.9	30.4	29.1
MCHC 33.0-38.0%	.001	34.1	32.5	34.3	33.2
1978:					
Number of workers		30	36	38	38
Creatinine* 0.6-1.2 mg/dl	.020	.99	.97	1.04	.91
Chicago - 1977:		ISE	EST	WT	
Number of workers		43	38	39	
BUN* 8.0-20.0 mg/dl	.048	15.2	16.4	14.2	
Albumin 3.5-5.0 g/dl	.055	4.6	4.4	4.3	
1978:					
Number of workers		24	27	16	
SGOT* 10-40 mU/ml	.033	29.1	27.1	24.0	
Proteint (Urine)	.035	18/24	10/17	25/27	

(continued)

TABLE 44 (continued)

ISE = Inexperienced Sewage-Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Workers
HM = Highway Maintenance Workers
WT = Water Treatment Workers
MLGW = Memphis Light, Gas and Water Workers

Test	p (Adjusted for age and race)	ISE	MLGW
Memphis - 1977:			
Number of workers		28	49
Glucose* (Blood) 65-100 mg/dl	.002	90.0	78.3
MCH 27.0-31.0 µµg	.001	31.5	29.1
MCHC 33.0-38.0 %	.001	36.2	34.1
1978:			
Number of workers		35	41
Total Bilirubin* 0.1-1.1 mg/dl	.041	.61	.48
Calcium (Blood) 8.5-10.5 mg/dl	.038	9.42	13.8

*Geometric Mean
**Normal Range
†Normal/Total Tested

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TABLE 45. RESULTS OF TUBERCULOSIS SKIN TESTING* OF CINCINNATI WORKERS

	Inexperienced sewage-exposed	Experienced sewer maintenance	Experienced sewage treatment	Highway maintenance
		Number of workers (percent)		
Number in group	34 (20)	47 (28)	37 (22)	50 (30)
TB test result				
Positive	3 (9)	23 (49)	7 (19)	26 (52)
Negative	31 (91)	24 (51)	30 (81)	24 (48)
Race				
Black	14 (41)	43 (92)	13 (35)	34 (68)
White	20 (59)	4 (8)	24 (65)	16 (32)
Age range, years				
20-24	7 (21)	1 (2)	0 (0)	1 (2)
25-29	12 (35)	9 (19)	9 (24)	3 (6)
30-39	5 (15)	12 (25)	12 (32)	7 (14)
40-49	6 (18)	12 (25)	8 (22)	20 (40)
50-75	4 (12)	13 (28)	8 (22)	19 (38)

No significant difference by group or for age, race and group interaction.
Significance of age, $p = .0001$
Significance of race, $p = .136$
Significance of group, $p = .018$

*Cumulative results of testing performed during years 1975-1978. There were no instances where test results changed from negative to positive for any particular worker.

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TABLE 46. TUBERCULOSIS SKIN TESTING BY AGE AND RACE CINCINNATI WORKERS
NUMBER OF WORKERS (PERCENT)

A. Age

Test result	Under 40 years	40 Years and over
Positive	10 (13)	49 (54)
Negative	68 (87)	41 (46)
Totals	78	90

Significance, p = .0001

B. Race

Test Result	Black	White
Positive	46 (44)	13 (20)
Negative	58 (56)	51 (80)
Totals	104	64

Significance, p = .136

diseases. Infectious diseases such as pneumonia and hepatitis were also included in these disease categories and there were no variations between groups. Laboratory tests such as pulmonary function tests and electrocardiograms failed to show any consistent differences. Therefore, it was concluded that exposure to wastewater had no detrimental effects on the general health of the workers and there were no overall differences in general health status between the work groups.

Virus Isolations

A total of 62 isolations were made from throat and rectal swabs collected from study participants in all three cities. No virus isolations were made from the stool specimens that were collected during the first year of the study in Cincinnati. One-half of all isolates were Herpes Simplex, less than one-third were enteroviruses (Table 47). About three-fourths of the isolations were made from throat swabs alone. Four were from both throat and rectal swabs collected at the same time.

A listing of the enterovirus isolations (Table 48) reveals a marked difference in identification of the isolates between Cincinnati and Chicago; no isolates of enteroviruses occurred in Memphis workers. Of the five enteroviruses isolated from Cincinnati workers and the six from Chicago, only one was common to both groups (Echo 9). Most isolates were from initial specimens collected. This occurred for five inexperienced sewage treatment plant workers in Chicago and, therefore, is not related to treatment plant exposure since they were not yet working.

The three sewage-exposed groups in Cincinnati were combined and compared with the control group in Cincinnati for enterovirus isolations (Table 49). Seven isolations were made from 1787 swabs collected from the sewage-exposed workers and two from 1128 swabs from control workers. This difference was not statistically significant ($p \leq .05$).

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TABLE 47. SUMMARY OF NUMBER OF VIRUS ISOLATIONS FROM ROUTINELY-COLLECTED THROAT AND RECTAL SWABS BY WORKER GROUP

	Total Number of Swabs Collected	Type of Virus Isolated				
		Enterovirus	Adenovirus	Rhinovirus	Herpes Simplex	Influenza Type A
Cincinnati:						
Inexperienced sewage-exposed	354	3	0	2	4	0
Experienced sewer maintenance	848	3	1	0	9	1
Experienced sewage treatment	585	1	0	1	2	2
Highway maintenance	1128	2	3	1	8	1
Chicago:						
Inexperienced sewage treatment	663	8	0	1	2	0
Experienced sewage treatment	616	3	0	0	0	0
Water treatment	472	2	0	0	2	0
Memphis:						
Inexperienced sewage treatment	306	0	0	0	1	0
Light, Gas and Water	354	0	0	0	2	0
Totals	5,326	22	4	5	30	4

TABLE 48. LIST OF ENTEROVIRUS ISOLATIONS FROM THROAT AND RECTAL SWABS

Worker	No. of months on job	Specimens Type	Specimens Date	Virus
Cincinnati				
Inexperienced Sewage Treatment Plant	3	TS&RS	7/77	Echo 3
Inexperienced Sewage Treatment Plant	15	RS	9/77	Echo 3
Highway Maintenance	N.A.	RS	10/77	Echo 21
Experienced Sewer Maintenance	N.A.	RS	7/78	Coxsackie B5
Experienced Sewer Maintenance	N.A.	TS	7/78	Echo 9
Experienced Sewer Maintenance	N.A.	TS	7/78	Echo 9
Experienced Sewage Treatment	N.A.	RS	7/76	Coxsackie B2
Highway Maintenance	N.A.	RS	10/75	Echo 21
Chicago				
Inexperienced Sewage Treatment	0	TS	9/76	Polio 1
Inexperienced Sewage Treatment	0	TS&RS	8/76	Polio 1
Inexperienced Sewage Treatment	0	TS	10/76	Polio 3
Inexperienced Sewage Treatment	0	TS	10/76	Polio 3
Inexperienced Sewage Treatment	0	RS	11/76	Polio 1
Inexperienced Sewage Treatment	14	TS	10/77	Coxsackie A13
Inexperienced Sewage Treatment	27	RS	11/78	Echo 9

(continued)

TABLE 48 (continued)

Worker	No. of months on job	Specimens Type	Specimens Date	Virus
Experienced Sewage Treatment	N.A.	TS&RS	11/76	Polio 3
Experienced Sewage Treatment	N.A.	TS	10/77	Echo 29
Water Treatment	N.A.	TS&RS	7/78	Coxsackie B4
Memphis				
None				

TS: throat swab; RS: rectal swab.
N.A.: Not applicable, applies to inexperienced workers only.

TABLE 49. ENTEROVIRUS ISOLATIONS FROM THROAT AND RECTAL SWABS COLLECTED FROM SEWAGE-EXPOSED AND CONTROL WORKERS IN CINCINNATI

	Number of swabs	Number of isolations
Sewage-exposed workers	1787	7
Controls	1128	2

p = .50 (chi-square)

Not counting isolations from inexperienced sewage plant workers before starting work, only two enterovirus isolations were made from Chicago specimens, a number too small to support statistical analysis.

One hundred nine throat and rectal swabs were collected at times of illness from study participants (Table 50). Six isolates were made from these specimens, none were enteroviruses.

Only 10 different enteroviruses were recovered from study participants compared to 18 from wastewater samples (Table 51). Of the 10 recovered from participants, five were also recovered from wastewater.

Bacterial Isolations

Stool specimens were used for Salmonella and Shigella isolations from Cincinnati study volunteers prior to July 1976 and all were found be be negative. Beginning in July, 1976, rectal swabs were routinely collected for bacterial isolations from all study participants. A total of six isolations of Salmonella were made (Table 52), all were from sewage treatment plant workers. Of those, four were from Cincinnati and two from Chicago. One of the Chicago isolates was made from an inexperienced sewage treatment plant worker from the first specimen collected and is, therefore, not related to the sewage exposure. The only Shigella isolate was from a Chicago water treatment plant worker. A comparison of number of isolations between combined sewage-exposed and control workers in Cincinnati (Table 53) revealed no significant difference between the groups.

There was, therefore, no evidence of increased Salmonella and Shigella infection in sewage-exposed workers.

Combined Isolations

Combined virus and bacteria isolations in Cincinnati sewage-exposed and control workers (Tables 49 and 53) resulted in 11 isolations from 1787 specimens in sewage-exposed workers and two isolations from 1128 specimens from control workers (Table 54). This difference was not statistically significant ($p = .15$ by chi-square with Yates correction).

Parasite Examination of Stool Specimens

Parasitologic examinations were performed on 332 stool specimens collected from a total of 136 workers, all of whom worked in Cincinnati. Serial specimens were collected from the experienced sewer maintenance and highway maintenance workers at three month intervals for one year (July 1975 to July 1976). Specimens from the inexperienced sewage-exposed employees were obtained over this same time period. Because of the relatively low rate of collection of stool specimens (about 60%), results of analyses of the first specimen collected from each worker have been evaluated in more detail than the rest.

TABLE 50. SUMMARY OF NUMBER OF VIRUS ISOLATIONS FROM THROAT AND RECTAL SWABS COLLECTED AT TIME OF ILLNESS

	Total Number of Swabs Collected	Type of Virus Isolated				
		Enterovirus	Adenovirus	Rhinovirus	Herpes Simplex	Influenza Type A
Cincinnati:						
Inexperienced sewage-exposed	10	0	0	0	1	0
Experienced sewer maintenance	26	0	0	0	0	0
Experienced sewage treatment	21	0	0	1	0	2
Highway maintenance	4	0	0	0	0	1
Chicago:						
Inexperienced sewage treatment	13	0	0	0	1	0
Experienced sewage treatment	27	0	0	0	0	0
Water treatment	2	0	0	0	0	0
Memphis:						
Inexperienced sewage treatment	6	0	0	0	0	0
Light, Gas and Water	0	0	0	0	0	0
Totals	109	0	0	1	2	3

TABLE 51. ENTEROVIRUS TYPES RECOVERED DURING THE STUDY

Viruses	From wastewater monitoring	From participants
Polio	1-3	1,3
Coxsackie	A15, B1, 3-5	A13, B2, 4, 5
Echo	1-4, 6, 7, 9 13, 18, 33	3, 9, 29, 31
Total	18	10

TABLE 52. SALMONELLA AND SHIGELLA ISOLATIONS (FROM RECTAL SWABS)

Worker Group	Isolation	Date of Specimen
Cincinnati		
Inexperienced Sewage Treatment Plant	*Salmonella enteriditis*	April, 1978*
Experienced Sewage Treatment Plant	*Salmonella enteriditis*	July, 1976
Experienced Sewage Treatment Plant	*Salmonella enteriditis*	Oct., 1976
Experienced Sewage Treatment Plant	*Salmonella* Spp.	April, 1978
Chicago		
Inexperienced Sewage Treatment Plant	*Salmonella enteriditis*	Dec., 1976**
Experienced Sewage Treatment Plant	*Salmonella enteriditis*	Oct., 1977
Water Treatment	*Shigella*	Jan., 1977
Memphis		
No isolations		

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*Sewage exposure began one year prior to isolation.
**Isolation made in initial specimen collected.

TABLE 53. BACTERIAL ISOLATIONS FROM RECTAL SWABS COLLECTED FROM SEWAGE-EXPOSED AND CONTROL WORKERS IN CINCINNATI

Worker Group	Number of Specimens	Number of Isolations
Sewage-exposed	942	4
Control	519	0

p = 0.34 (chi-square)

TABLE 54. COMBINED BACTERIAL AND VIRAL ISOLATIONS FROM SEWAGE-EXPOSED AND CONTROL WORKERS IN CINCINNATI

Worker Group	Number of Specimens	Number of Isolations
Sewage-exposed	1787	11
Control	1128	2

p = 0.15 (chi-square)

Forty-eight sewer maintenance workers were studied. They were experienced workers who had worked for at least one year and whose jobs involved direct exposure to raw sewage. Workers who drove trucks and heavy equipment, or whose jobs otherwise did not involve direct contact with sewage were not included. Sewer maintenance workers were compared to: 1) 19 inexperienced employees who had not yet been exposed to sewage; and 2) 69 highway maintenance workers. The median age of these groups was 38, 38 and 26 years, respectively. Both groups in the comparison population represented the same socioeconomic and racial population as the study groups.

Results of the parasitologic examination of initial stool specimens collected from the study participants are shown in Table 55. Of the total of 10 isolations made, all were from specimens of nonsewage-exposed workers (eight from highway maintenance and two from inexperienced employees from their initial stool specimens). The difference between the exposed and non-exposed groups is statistically significant (p = .05). All infections were reported to be asymptomatic.

For three men from the sewer maintenance group and three from the highway maintenance group, a parasite was isolated from their second or later stool specimen that was not found in their initial specimen: *Giardia lamblia* (two sewer maintenance and one highway maintenance worker) and *Entamoeba coli* (one sewer maintenance and two highway maintenance workers). *Giardia lamblia* was the only parasite isolated from two or more consecutive specimens from the same worker; an asymptomatic infection in one sewer maintenance worker has continued for about two years. Two workers received treatment for giardiasis; one worker continued to shed cysts and one did not.

With the exception of *Stronglyoides stercoralis*, all parasites isolated are protozoan species. Two species recovered, *Entamoeba coli* and *Endolimax nana* are nonpathogenic gastrointestinal parasites, widely distributed and common to humans. *E. nana* was found exclusively in the control group, highway maintenance; most of the isolations were from persons working closely together. *E. coli* was found in both sewer maintenance and highway maintenance workers. The pathogenic protozoan, *Isospora* spp., was isolated from specimens of two highway maintenance workers.

Some workers from all three worker groups were discovered to be infected with the flagellate protozoan, *Giardia lamblia*. Although *G. lamblia* is not a tissue invader, it is considered pathogenic because gastrointestinal symptoms such as recurrent enteritis and diarrhea are common when this flagellate is present; also, heavy infections are suspected of inhibiting absorption in the human intestinal tract. When questioned, all men with *Giardia* reported an absence of symptoms.

Few population studies are available with which to compare our results. The overall isolation rate of seven percent from initial specimens collected from the municipal public works employees involved in our study is only slightly lower than the eight percent rate among patients with gastrointestinal disorders in a Staten Island, New York, community (25). These patients ranged in age from eight to 74 years and about two-thirds were female.

TABLE 55. RESULTS OF THE PARASITOLOGIC EXAMINATION OF THE INITIAL STOOL SPECIMENS COLLECTED FROM STUDY PARTICIPANTS

Worker group	No. of men	No. of isolations	Parasite (no. of workers)
Exposed:			
Sewer maintenance	48	0	--
Nonexposed:			
Highway maintenance	69	8	*Endolimax nama* (5) *Giardia lamblia* (1) *Isospora spp.* (2)
Inexperienced sewage-exposed*	19	2	*Giardia lamblia* (1) *Strongyloides stercoralis* (1)
	p = .05		

*Specimen collected just as sewage employment began and are therefore considered to be unexposed at time of specimen.

Approximately two percent of those patients contracted *Giardia lamblia* infections abroad.

In another survey of patients with gastrointestinal complaints in a lower socioeconomic community in Brooklyn, New York, isolation rates varied from 19.5% in patients not suspected of harboring parasites to 33.7% in patients suspected of harboring an infection (26). Nematode species were the predominant parasites isolated in both groups (11.0% and 20.9%, respectively), whole protozoan species represented the majority of isolates in the present study and in the Staten Island study (6.5%). The portion of the Brooklyn group more comparable to those in our study are those not suspected of harboring parasites. This group had a 7.6% isolation rate for protozoan infections, compared to 6.2% in our study.

The most commonly isolated parasite in our study, *G. lamblia* (3.5%) was also most commonly isolated in the Staten Island study (3.2%), but was found in only 0.6 and 2.2%, respectively, for the two groups of patients in Brooklyn. *G. lamblia* was isolated from 3.8% of the stool specimens examined in 1976 by the Center for Disease Control (27).

Paired sera from 25 age and race matched Chicago sewage treatment plant and water treatment plant workers were analyzed for *Toxocara* antibody by Dr. Peter M. Schantz of the Center for Disease Control using the ELISA method. Only one worker, a water treatment plant employee, had a positive titer at $\log_2$ of 5.

The present study shows that parasite infection is not a significant risk in workers occupationally exposed to sewage.

SEROLOGICAL SURVEY

The results of the serological survey are divided into three components: virus serology, bacterial serology, and immunoglobulins.

Virus Serology

The major portions of this survey were completed in two phases. The first phase involved testing of Cincinnati and Chicago workers for antibodies to 31 viruses. The second phase included testing of study volunteers in all three cities for a group of 17 viruses. In addition a family study was performed which involved testing for six viral antibodies in single serum specimens for workers and household members. Testing for Hepatitis A and B was performed at selected intervals and the results are discussed separately. For comparisons where $p \leq .05$, results are summarized and contingency tables are presented. Significance values for all comparisons are included in appendices.

First Phase of Virus Serology Survey--

The viruses included in this phase of testing are those listed on Table 2. Sera from a total of 166 Cincinnati workers and 85 Chicago workers (Table 4) were analyzed for antibodies to those viruses. The serum samples were chosen to demonstrate antibody changes during the enteroviral season. For most workers the testing was performed on sera collected during July 1976, January 1977 and October 1977. The Chicago Waterworks employees were not recruited into the study until January 1977 and for them, therefore, only two specimens were analyzed. The serologic results were evaluated in three ways: (1) distribution of antibody levels and titer level changes within each city for each virus separately, (2) cumulative fourfold titer rises in each city, and (3) illness rates and titer level change comparisons. In each analysis there were several comparisons which were statistically significant.

Distributions and titer level changes--The distribution of antibody titers was analyzed between groups within each city for each serum collection period and titer level changes from one period to the next were compared between groups in each city. The statistical significance levels for all these comparisons are included in Appendix C and D. There were five statistically significant differences at $p \leq .01$, all in Cincinnati and an additional 8 at $p \leq .05$ (Table 56). In October 1977, the experienced sewer maintenance workers in Cincinnati had higher titer levels to Polio 2 antibody ($p = .003$) than the other groups. Herpes Simplex antibody levels were highest in the highway maintenance group and lowest in the inexperienced sewage exposed ($p = .001$) in January 1977. For Echo 6 for the period January - September 1977 there were significantly more titer level increases ($p = .006$) for the experienced sewer maintenance workers in Cincinnati. For this same time period there were significantly more decreases ($p = .003$) in antibody to adenovirus among inexperienced sewage-exposed workers in Cincinnati. Contingency tables for all significantly different ($p \leq .05$) antibody level distributions and titer level changes are presented in Tables 57 and 58 for Cincinnati and Chicago, respectively.

Cumulative fourfold titer rises--In addition to comparisons of antibody level for each virus separately, comparisons of antibody rises for all viruses tested were also made. Both seroconversions (fourfold or greater increases in antibody in persons without antibody at the start) or significant boosts in titer (fourfold or greater increases in antibody or persons with antibody) were compared. In the first phase of the virus serology survey in Cincinnati there were no significant differences between worker groups for either of these comparisons (Table 59). For Chicago workers, however, there were significantly more ($p = .043$) seroconversions in the experienced sewage treatment groups (Table 59).

Illness rate - antibody level change comparison--Fourfold or greater increases in titer level to a virus usually indicates an infection which may be either clinical or subclinical. An effort was made to determine whether illness rates for workers with fourfold titer level increases are higher than those not having such increases. For Cincinnati workers during the July 1976 to January 1977 period, 52 workers had fourfold or greater titer level

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TABLE 56. STATISTICALLY SIGNIFICANT COMPARISONS ($p \leq .05$) OF TITER LEVEL DISTRIBUTIONS AND CHANGES - FIRST PHASE OF VIRUS SEROLOGY SURVEY

City	Virus	Time period		Result
Cincinnati	Polio 2	7/76	.043	Experienced sewer maintenance workers have highest titer levels
Cincinnati	Polio 2	1/77	.003	Experienced sewer maintenance workers have highest titer levels
Cincinnati	Echo 8	7/76	.023	Highway maintenance workers have highest titer levels
Cincinnati	Echo 1	1/77	.018	Highway maintenance workers have highest titer levels
Cincinnati	Herpes Simplex	1/77	.001	Experienced sewer maintenance and highway maintenance workers have highest titer levels
Cincinnati	Herpes Simplex	10/77	.021	Experienced sewer maintenance and highway maintenance workers have highest titer levels
Cincinnati	Echo 6	1-10/77	.006	Experienced sewer maintenance workers have more increases
Cincinnati	Adenovirus	1-10/77	.003	Inexperienced sewage-exposed workers have more decreases
Chicago	Echo 8	10/77	.048	Water treatment workers have highest titer levels
Chicago	Coxsackie B3	7/76	.045	Experienced sewage treatment workers have highest titer levels
Chicago	Herpes Simplex	10/77	.046	Water treatment workers have highest titer levels
Chicago	Echo 6	1/77	.008	Water treatment workers have highest titer levels
Chicago	Echo 4	7/76-1/77	.046	More increases in inexperienced group

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TABLE 57. FIRST PHASE OF VIRUS SEROLOGY SURVEY CONTINGENCY TABLES CINCINNATI $p \leq .05$

		Titer level <2	2	4	8	16	32	64	≥128	p	Geometric Mean
Polio 2	ISE	3	0	1	3	3	12	6	7	.043	27.7
(7/76)	ESM	0	0	1	1	8	9	15	6		40.6
	HM	1	1	3	2	9	8	7	17		37.0
	EST	1	2	3	5	5	7	4	14		29.3
Polio 2 (1/77)	ISE	2	2	0	2	3	11	8	8	.003	31.2
	ESM	0	0	0	2	10	5	16	7		42.1
	HM	1	2	2	2	11	5	9	16		34.9
	EST	1	3	0	6	6	10	1	13		27.7
Echo 8	ISE	18	10	2	3	2	0	0	0	.023	*
(7/76)	ESM	18	11	5	4	2	0	0	0		2.0
	HM	13	11	15	6	1	2	0	0		2.9
	EST	25	7	3	3	3	0	0	0		*

		Titer level <2	2	4	8	16	32	64	≥128	p	Geometric Mean
Echo 1 (1/77)	ISE	21	10	2	3	0	0	0	0	.018	*
	ESM	24	6	3	4	3	0	0			*
	HM	13	19	9	2	4	1	1			2.7
	EST	18	9	2	10	1	0	0	0		2.3
HSV	ISE		22	1	4	2	4	3	0	.001	3.2
(01/77)	ESM		7	3	7	6	10	2	3		11.5
	HM		11	3	8	8	15	3	0		9.3
	EST		15	4	7	9	3	1	1		5.0
HSV	ISE		12	0	3	0	4	4	0	.021	4.9
(10/77)	ESM		7	2	6	9	11	2	3		12.5
	HM		10	3	6	11	12	7	0		11.0
	EST		13	8	3	11	2	2	1		5.5

(continued)

TABLE 57 (continued)

		Titer level changes								
		Increases				No change	Decreases			
		4	3	2	1		1	2	3	4
Echo 6	ISE	0	0	0	3	15	5	0	0	0
(1-10/77)	ESM	1	1	3	11	21	3	0	0	0
p = .006	HM	0	0	0	4	34	10	0	1	0
	EST	0	0	0	4	28	8	0	0	0
Adeno	ISE	0	0	0	2	9	12	0	0	0
(1-10/77)	ESM	0	0	2	6	23	3	2	0	3
p = .003	HM	0	0	1	9	28	7	0	0	0
	EST	0	0	0	0	30	7	1	2	0

*Below minimum detection level

TABLE 58. FIRST PHASE OF VIRUS SEROLOGY SURVEY CONTINGENCY TABLES CHICAGO $p \leq 0.05$

		Titer level									Geometric Mean
		<2	2	4	8	16	32	64	>128	p	
Cox B3	ISE	10	6	7	1	2	1	0	0	.045	2.5
(7/76)	EST	13	0	4	5	2	1	3	0		3.8

		Titer level								Geometric Mean
		<4	4	8	16	32	64	>128	p	
HSV	ISE	9	3	4	9	4	1	0	.046	6.3
(10/77)	WT	5	0	1	4	8	5	0		14.5
	EST	10	2	4	4	5	2	3		8.0

		Titer level									Geometric Mean
		<2	2	4	8	16	32	64	>128	p	
Echo 6	ISE	1	1	10	6	5	2	3	1	.008	9.4
(1/77)	WT	1	2	2	6	4	3	5	0		12.9
	EST	2	10	2	4	3	7	3	0		7.6

		Titer level									Geometric Mean
		<2	2	4	8	16	32	64	≥128	p	
Echo 8 (10/77)	ISE	23	6	1	0	0	0	1	0	.048	*
	WT	10	3	1	6	3	0	0	0		2.9
	EST	18	7	3	3	0	0	0	0		*

*Below detection level

TABLE 59. COMPARISON OF CUMULATIVE FOUR-FOLD TITER LEVEL INCREASES AND SEROCONVERSION IN INITIAL PHASE OF VIRUS SEROLOGY SURVEY

Worker group	Number of workers	Number of fourfold or greater titer level increases	Number of seroconversion
Cincinnati			
Inexperienced sewage exposed	35	46	18
Experienced sewer maintenance	40	79	13
Experienced sewage treatment	40	62	10
Highway maintenance	49	81	12
Chicago*			
Inexperienced sewage treatment	28	6	1**
Experienced sewage treatment	29	14	8**
Water treatment	31	7	3**

* Only results from January 1977 and October 1977 sera used in comparisons.

** $p = .043$

No other significant differences ($p \leq 05$)

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increases and 72 did not. These workers were from the inexperienced sewage exposed, experienced sewer maintenance, experienced sewage treatment plant, and highway maintenance groups which were shown not to have significantly different rates of titer level increases. The rate of illness was the same for workers with the titer level increases as for those without (p = .90 for July-September 1976, p = .17 for October-December 1976). The rate of contact to determine illnesses was the same for workers with titer level increases as for those without. Thus, it also can be concluded that the infections represented by the fourfold or greater titer level increases appear to be subclinical in nature.

Summary of First Phase of Virus Serology--

A total of 314 comparisons were made of the data collected in the first phase of the virus serology survey: 31 viruses x two cities x five comparisons (three comparisons of titer level distributions and two comparisons of titer level changes) plus four comparisons of cumulative titer level rises. Using a significance level $p \leq .05$, five comparisons out of 100 would be expected to be significant by chance alone; for 314 comparisons about 15 such differences would be expected. The 314 comparisons made (Table 60) resulted in 13 with $p \leq .05$, about equally divided between those with the exposed (study) group with higher values and those with a control group higher. All three statistically significant ($p \leq .05$) titer level change comparisons involved an excess of increases among wastewater-exposed workers. There were more cumulative seroconversions in the experienced sewage treatment plant workers in one of the two cities studied, Chicago. In conclusion, therefore, the first phase of the virus serology survey did not find evidence of increased viral infections as indicated in distribution of antibody levels, however titer level change comparisons suggest some risk of viral infections among the wastewater-exposed workers.

Second Phase of Virus Serology Survey--

The 17 viruses included in this survey are shown in Table 61. The workers included in this group were from all three study cities. Sera collected in the January and October 1978 quarters, or the closest available date, were analyzed for the various work groups (see Table 4). In addition, initial sera from the inexperienced sewage-exposed groups were also analyzed. Differences in distribution of titer levels, titer level changes and cumulative fourfold titer rises were evaluated as they were for the initial phase of the virus serology survey. In addition, comparisons were made between the levels of the combined three-city inexperienced exposed worker groups and those of the combined three-city control groups.

Titer levels in first sera collected from inexperienced (new) sewage-exposed workers were compared with levels in January 1978 sera to determine if titer level rises occurred as a result of initial occupational exposure to wastewater. Results of first sera collected from new workers were also compared to those from their last sera.

Distribution and titer level changes--The significance values for the comparison of titer levels and titer level changes in the January and October 1978 sera are presented in Appendices E, F and G for Cincinnati, Chicago and

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TABLE 60. SUMMARY OF RESULTS OF THE FIRST PHASE OF VIRAL SEROSURVEY

Comparisons: 314 comparisons between groups (31 viruses x 5 comparisons x 2 cities) plus 4 comparisons of cumulative fourfold titer rises

Differences: 13 significant at $p \leq .05$ (5 at p .01)

a) 10 differences in level of antibody

control group higher in 4, both a control and study group higher in 2, and study group higher in 3

b) 3 differences in changing antibody titers

study group higher for two and one study group highest and lowest for one comparison

TABLE 61. VIRUSES INCLUDED IN SECOND PHASE OF VIRUS SEROLOGY SURVEY*

Polio	1, 2, 3
Coxsackie	A9, B1, B2, B3, B4, B5
Echo	3, 6, 8, 9, 11, 21
Adenovirus	
Herpes Simplex	

*Sera collected in January 1978 and October 1978 quarters from workers in all three cities were used in this survey.

TABLE 62. SECOND PHASE OF VIRUS SEROLOGY SURVEY LIST OF SIGNIFICANCE LEVELS (p VALUES ≤ 0.05) FROM TESTING OF JANUARY 1978 AND OCTOBER 1978 SERA

City	Virus	Time period	p	Result
Cincinnati	Herpes Simplex	1/78	.008	Highway and experienced sewer maintenance workers have highest levels
Cincinnati	Adenovirus	1/78	.041	Inexperienced sewer maintenance workers have highest levels
Cincinnati	Herpes Simplex	10/78	.009	Highway and experienced sewer maintenance workers have higher levels
Cincinnati	Echo 11	10/78	.033	Experienced sewer maintenance workers have highest levels
Cincinnati	Coxsackie A9	1-10/78	.035	Inexperienced sewage exposed and experienced sewage treatment plant workers have fewer increases; experienced sewer maintenance workers have more increases
Chicago	Echo 11	1/78	.036	Water treatment workers have higher levels
Memphis	Coxsackie A9	1/78	.012	Inexperienced sewage treatment plant workers have higher levels*
Memphis	Coxsackie A9	10/78	.002	Inexperienced sewage treatment plant workers have higher levels*

*Comparison of results from first sera and January 1978 sera did not reveal any differences, therefore these differences appear to be unrelated to the sewage exposure.

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additional five at $p \leq .05$ (Table 62). No significant differences ($p \leq 0.01$) were found for the Chicago comparisons. In Cincinnati, Herpes Simplex antibody levels in January and October 1978 were higher ($p = .008$ and $.009$, respectively) in the sewer maintenance and highway maintenance groups than in the inexperienced sewage-exposed and experienced sewage treatment plant worker groups. In Memphis antibody levels to Coxsackie A9 virus were significantly higher in the inexperienced sewage treatment plant workers in October 1978 ($p = 0.002$) than in the Memphis Light, Gas and Water workers. Of the five other comparisons for which $p \leq 0.05$, wastewater exposed workers were higher in three, lower in one and in the fifth two wastewater exposed groups were lower and one was higher. Contingency tables for all comparisons where $p \leq .05$ are presented in Table 63.

Cumulative four-fold titer rises--Cumulative four-fold titer level increases and seroconversion for the 17 viruses included in the second phase are not different between the worker groups in any of the cities either separately or combined (Table 64).

Combined-city comparisons--Statistical comparisons were made of the titer level distributions and titer level changes for the combined three-city inexperienced exposed and control workers. This differs from the comparisons in Table 64 which only involved cumulative four-fold or greater titer rises for all the tests in the final virus serology survey and the subgroup of fourfold rises where the initial titer level was below the detection limit for the test (seroconversions). Results (Appendix H) revealed two differences at $p \leq .01$ and four where $.01 < p \leq .05$. For three of the differences the control workers had higher levels (Table 65), for Echovirus B in January 1978 sera and for Herpes Simplex virus in both January and October 1978. The exposed workers had higher titers to both Coxsackie A9 and Adenovirus in October 1978 and also had more titer level decreases for Poliovirus 2. Contingency tables are included in Table 66.

Comparison of first sera from inexperienced workers--The second phase of the virus serology survey also included testing the initial sera for the inexperienced sewage-exposed workers in Cincinnati, and the inexperienced sewage treatment plant workers in Chicago and Memphis. Two comparisons were made using results from the first sera: (1) comparison with results from January 1978 sera city by city and (2) comparison of titer level changes from first sera to January 1978 sera between cities. The first type of comparison was designed to determine if antibody levels increased on a city-by-city basis. The second type was made to determine if there were differences in antibody level changes between cities due to differences in exposure level of the workers. For both of these types of comparison, no significant differences were detected at $p \leq .01$ and only one was significant at $p \leq .05$ (Appendix I). For Echovirus 3, titer levels in the inexperienced Memphis workers were somewhat higher in January 1978 than in the first sera: 13 of 41 workers had levels ≥ 4 in their first serum and 20 of 41 had levels ≥ 4 in January 1978 serum ($p = 0.038$). The higher titer levels to Coxsackie A9 in the Memphis inexperienced sewage treatment plant workers in January and October 1978 (Table 62) appear not to be job-related since there was no difference between the first sera from these workers and that from January 1978.

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TABLE 63. SECOND PHASE OF VIRUS SEROLOGY SURVEY (JANUARY AND OCTOBER 1978 SERA) CONTINGENCY TABLES-CINCINNATI, AND MEMPHIS $p \leq .05$

Cincinnati

		Titer Level									Geometric Mean
		<2	2	4	8	16	32	64	≥128	p	
Echo 11	ISE	18	5	2	7	1	1	0	0	.033	2.2
(1/78)	ESM	14	9	12	3	3	0	0	0		2.5
	HM	19	13	4	4	2	1	0	0		2.1
	EST	22	8	2	5	1	0	2	0		2.1

		Titer Level									Geometric Mean
		<2	2	4	8	16	32	64	≥128	p	
Adenovirus (1/78)	ISE	4	4	7	8	6	5	0	0	.041	11.7
	ESM	3	4	18	8	2	4	0	0		9.7
	HM	3	8	12	17	1	2	0	0		9.1
	EST	6	10	9	13	4	0	0	0		7.1

		Titer Level								Geometric Mean
		<4	4	8	16	32	64	≥128	p	
HSV	ISE	13	1	0	7	9	3	1	.008	7.6
(1/78)	ESM	4	4	1	8	13	6	2		17.7
	HM	2	2	5	12	14	5	3		20.6
	EST	9	0	6	17	5	3	1		9.9
HSV	ISE	13	0	1	6	9	4	1	.009	8.1
(10/78)	ESM	5	1	6	8	14	5	2		16.4
	HM	1	0	4	19	13	5	1		21.3
	EST	10	3	5	12	9	0	1		8.1

		Titer Level Changes								
		Increase				No change	Decrease			
		4	3	2	1		1	2	3	4
Cox A9	ISE	0	1	3	5	20	5	0	0	0
(1-10/78)	ESM	0	2	0	9	12	13	5	0	0
p=.035	HM	0	0	0	9	23	9	1	0	0
	EST	0	1	1	7	27	4	0	0	1

(continued)

TABLE 63 (continued)

Chicago						$p \leq .05$					
		Titer Level									Geometric
		<2	2	4	8	16	32	64	≥128	p	Mean
Echo 11	ISE	25	8	8	2	2	0	0	0	.036	*
(1/78)	WT	7	12	2	1	0	2	0	0		2.4
Memphis											
Cox A9	ISE	7	1	4	6	10	5	5	3	.012	11.2
(1/78)	MLGW	10	12	9	7	5	2	5	0		4.7
Cox A9	ISE	6	2	3	6	5	10	4	6	.002	14.4
(10/78)	MLGW	7	15	8	5	6	2	3	1		4.7

* Below detection level

TABLE 64. COMPARISON OF CUMULATIVE FOURFOLD TITER LEVEL RISES AND SEROCONVERSIONS IN SECOND PHASE OF VIRUS SEROLOGY SURVEY

Worker group	No. of workers	No. of fourfold or greater rises	No. of seroconversion
Cincinnati			
Inexperienced sewage-exposed	34	41	5
Experienced sewer maintenance	40	38	15
Experienced sewage treatment	41	37	14
Highway maintenance	43	31	9
Chicago			
Inexperienced sewage treatment	45	46	12
Water works	24	20	6
Memphis			
Inexperienced sewage treatment	41	42	14
MLG&W	50	39	15
Combined			
Sewage exposed	201	205	60
Controls	117	90*	30

*p = .106 (chi-square)

TABLE 65. COMPARISON OF SECOND PHASE OF VIRUS SEROLOGY FOR COMBINED THREE-CITY INEXPERIENCED SEWAGE EXPOSED AND CONTROL GROUPS ($P < 0.05$)

Virus	Time period	p	Result
Polio 2	January-October 1978	.046	More decreases in exposed workers
Coxsackie A9	October 1978	.003	Higher levels in exposed workers
Echo 8	January 1978	.040	Controls higher
Adenovirus	October 1978	.048	Exposed higher
Herpes Simplex	January 1978	.008	Controls higher
Herpes Simplex	October 1978	.035	Controls higher

TABLE 66. CONTINGENCY TABLES FOR COMPARISONS OF SECOND PHASE OF VIRUS SEROLOGY FOR COMBINED THREE-CITY INEXPERIENCED SEWAGE EXPOSED AND CONTROL GROUPS* ($p \le 0.05$)

January 1978

Echo 8	Titer level <2	2	4	8		
Inexperienced sewage-exposed	113	7	0	0	(controls higher)	.040
Control	99	12	4	2		

Herpes Simplex	<4	4	8	16	32	64	128		
Inexperienced sewage-exposed	36	4	8	28	27	11	2	(controls higher)	.008
Control	13	5	14	29	35	13	8		

October 1978

	Titer level									
Coxsackie A9	<2	2	4	8	16	32	64	128	Geometric Mean	
Inexperienced sewage-exposed	23	11	7	15	18	12	14	12	9.9	.003
Control	13	25	17	17	10	13	9	4	6.7	

Adenovirus	<4	4	8	16	32	64	128	Geometric Mean	
Inexperienced sewage-exposed	16	24	32	30	12	7	0	8.9	.048
Control	25	26	33	18	9	2	2	6.8	

Herpes Simplex	<4	4	8	16	32	64	128	Geometric Mean	
Inexperienced sewage-exposed	32	5	11	16	34	10	4	11.7	.035
Control	13	3	9	36	34	13	7	18.8	

January-October 1978

	Titer Level Change							
	Increases					Decreases		
Polio 2	-3	-2	-1	0	1	2	3	
Inexperienced sewage-exposed	0	8	22	70	20	3	2	.046
Control	1	5	20	61	14	3	0	

(more decreases inexperienced sewage exposed)

*Number of workers: inexperienced sewage-exposed 125 and controls 117.

For the inexperienced workers another important comparison is the change in prevalence from the first to last sera (October 1978) collected. Prevalence was defined as: presence of antibody at ≥ 2 titer level. There were no significant differences ($p \leq .05$) in prevalence of antibody titer for the inexperienced workers. For the control workers in Memphis, the number of workers with the antibody to Echovirus 6 at ≥ 2 was higher in the last sera collected than in the January 1978 sera.

Summary of second phase of virus serology--The total number of significant comparisons ($p \leq .05$) was 16 (Table 67) which is about what would be expected by chance for the 280 comparisons made. For six of these comparisons the control group was higher than at least one exposed group. Three of the 16 comparisons where $p \leq .05$ involved titer level changes where at least one exposed group had more changes than the control group for each of these comparisons. In all three cities the cumulative fourfold titer level rises were slightly higher in the exposed workers than in the controls but the differences for each city or for the combined cities was not significant at $p \leq .05$. For only one virus (Echo 3) and in only one city (Memphis) did antibody titers increase in inexperienced workers from the first sera collected to the January 1978 sera. In summary, the second phase of the virus serology did not reveal any substantial evidence for increased viral infection among wastewater exposed workers.

Age-Race Effect--

The nonexposed workers in all three cities were somewhat older than the exposed workers. In Chicago and Memphis a higher percentage of the nonexposed workers than exposed workers were black. In Cincinnati the nonexposed workers, on average, had the same racial composition as the exposed workers but on a group-by-group basis had a higher percentage of black workers than two of the exposed worker groups and a lower percentage than the third.

For Hepatitis A, virus antibody levels have been found to increase with age (28,29). In order to determine if either age or race were significant factors in the virus serologic surveys, results of the second phase of the serologic survey were compared according to race and age by city and by worker group. Results from those workers below the median age were compared with those above the median age. Results from sera collected from both the January 1978 and October 1978 quarters were used.

The number of comparisons involved in these procedures was 408 in Cincinnati [17 viruses x four worker groups x three comparisons (January; October; and January-October) x two factors (age and race)], and 204 each in Chicago and Memphis where only two worker groups per city were involved. There were a total of 11 comparisons where $p \leq .05$ one of which is significant where $p \leq .01$ (Table 68). Two of the 11 significant comparisons involved a race effect: in one, black workers had higher levels, and in the other black workers had more titer level decreases. Of the nine significant age comparisons, young workers had higher titer levels in six cases and more increases in another.

In Cincinnati, younger workers in the experienced sewer maintenance and sewage treatment plant groups had higher titer levels to adenoviruses in January 1978 (p = .011 and .001, respectively). In the experienced sewage

TABLE 67 . SUMMARY OF RESULTS OF COMPARISONS OF FIRST JANUARY 1978 AND OCTOBER 1978 SERA FROM SECOND PHASE OF VIRUS SEROLOGY SURVEY

Comparisons: Total of 280 comparisons - 153 comparisons between exposed and control groups (17 viruses x 3 comparisons x 3 cities), 119 comparisons involving inexperienced workers only (17 viruses x 7 comparisons) and 8 comparisons involving cumulative titer level changes

Differences: 16 statistically significant at $p \leq .05$ (5 of these were at $p \leq .01$)

a) 13 differences in level of antibody

control group higher in 5, both a control and study group in 2, and study groups in 6.

b) 3 differences in changing antibody titer

more increases in 1 study group, fewer in 2; more decreases in a study group; and higher titer levels in January 1978 sera than in the first serum collected in one city.

TABLE 68. SUMMARY OF DIFFERENCES ($p \leq 0.05$) IN VIRUS ANTIBODY LEVEL FOR GROUPS DIVIDED BY AGE* AND RACE

Difference	City	Worker group	Date	Parameter	Virus	p
Young higher	Cincinnati	Experienced sewer maintenance	1/78	Age	Adenovirus	.011
Young higher	Cincinnati	Experienced sewage treatment	1/78	Age	Adenovirus	.010
Black higher	Cincinnati	Experienced sewage treatment	1/78	Race	Echo 3	.011
More decreases in blacks	Cincinnati	Experienced sewage treatment	1/78 & 10/78	Race	Polio 2	.021
Older higher	Memphis	Inexperienced sewage-exposed	10/78	Age	Echo 6	.021
More increases in young	Memphis	Inexperienced sewage-exposed	1/78 & 10/78	Age	Echo 9	.038
Young higher	Memphis	Control	1/78	Age	Coxsackie B2	.045
Young higher	Memphis	Control	1/78	Age	Coxsackie B4	.018
Young higher	Memphis	Control	1/78	Age	Adenovirus	.021
Young higher	Memphis	Control	10/78	Age	Adenovirus	.033
Older higher	Memphis	Control	10/78	Age	Polio 2	.045

*Workers divided into those above median and those below median age.

treatment plant group, black workers had higher titer levels to Echo 3 virus in January 1978 ($p = .011$) and more black workers than white workers had decreasing titer levels to Poliovirus 2 for January to October 1978 ($p = .021$).

Neither the inexperienced exposed workers or the nonexposed workers in Cincinnati were found to have different results by age or race. In Chicago no significant age or race differences were detected.

Race differences were not detected in Memphis. However, the older inexperienced exposed workers had higher titer levels to Echo 6 virus in October 1978 ($p = .021$) and the younger workers in this group had more titer level increases for Echo 9 virus from January to October 1978 ($p = .038$). In four comparisons younger control workers had higher titer levels, January 1978 Coxsackie B2 ($p = .045$), January 1978 Coxsackie B4 ($p = .018$), January 1978 Adenovirus ($p = .021$) and October 1978 Adenovirus ($p = .033$) and in one comparison older workers had higher titer levels, October 1978 Poliovirus 2 ($p = .045$).

The number of significant comparisons, 10, is less than the number expected by chance at $p \leq .05$ which is 40. Most of these differences involved higher titer levels in younger workers. It is not thought that age and race differences affected study results.

Worker Exposure - Virus Serology Comparisons--

City-by-city comparison--As has been mentioned earlier study participants were ranked into one of two exposure levels for liquid/solids and airborne bacteria exposure: (1) high or (2) low. These rankings are in all cases relative to fellow workers in the same worker group in the same city. Job observations and environmental monitoring data even make it possible to separate the control group into "high and low exposure categories." The number of workers in the various groups was previously presented in Table 41. Comparisons of titer levels and titer level changes were made within the exposed group on a city-by-city basis (17 viruses x three times or time periods x two exposures x two group comparisons x three cities = 612 comparisons) and between those sewage workers with high exposure compared to the control group workers with low exposures, again on a city-by-city basis (306 comparisons). The purpose of these comparisons was to determine if degree of liquid/solids or airborne bacterial exposure were associated with higher antibody titer levels or more titer level changes.

For all these comparisons there were 10 where $p \leq .05$ (Tables 69 and 70), nine of which had the difference in a direction consistent with a waste effect. For the comparisons involving only inexperienced sewage exposed workers, there were six with $p \leq .05$. In one of the six a lower exposed group had higher titer levels; but, for the other five, the higher exposed group had higher titer levels: two involved liquid/solids exposure (both Cincinnati) and three aerosol exposure (two in Chicago and one in Memphis). There were four comparisons between "high-exposed" wastewater workers and "low-exposed" control workers where $p \leq .05$, all were in Memphis and in all the wastewater workers were higher. Two of the differences involved liquid/ solids exposure and two aerosol exposure.

TABLE 69. SUMMARY OF FINAL VIRUS SEROLOGY/EXPOSURE LEVELS COMPARISONS CITY-BY-CITY

Inexperienced workers only

Aerosol exposure

17 viruses x 3 cities x 3 comparisons = 153 procedures
4 tests $p \leq .05$ (2 tests $p \leq .01$)

Antibody levels - higher titers: 1 lower exposure, 2 higher exposure

Titer level changes: increases with higher exposure

Wastewater exposure

17 viruses x 3 cities x 3 comparisons = 153 procedures
2 tests $p \leq .05$ (1 test $p \leq .01$)

Antibody levels - higher titers: 1 higher exposure

Titer level changes: increases with higher exposure

Inexperienced vs. controls

Aerosol exposure

17 viruses x 3 cities x 3 comparisons = 153 procedures
2 tests $p \leq .05$ (1 test $p \leq .01$)

Antibody level - higher titers: exposed group higher

Titer level changes: more decreases in exposed group

Wastewater exposure

17 viruses x 3 cities x 3 comparisons = 153 procedures
2 tests $\leq .05$

Antibody levels - higher titers: 2 higher levels in exposed groups

TABLE 70. COMPARISON OF FINAL VIRUS SEROLOGY RESULTS AND EXPOSURE LEVELS, LIST OF SIGNIFICANCE LEVELS (p VALUES) <0.05 (CITY-BY-CITY)

City	Virus	Time	p	Group with higher levels
		Inexperienced workers only*		
Aerosol exposure				
Cincinnati	Adenovirus	10/78	.010	Low exposure
Chicago	Echo 21	1/78	.018	High exposure
Chicago	Echo 21	10/78	.007	High exposure
Memphis	Echo 9	1-10/78	.026	More decreases in high exposure
Wastewater exposure				
Cincinnati	Coxsackie A9	10/78	.004	High exposure
Cincinnati	Coxsackie B4	1-10/78	.044	More increases in high exposure
		Inexperienced vs. controls**		
Aerosol exposure				
Memphis	Coxsackie A9	10/78	.009	Inexperienced sewage-exposed
Memphis	Echo 9	1-10/78	.033	More decreases in inexperienced sewage-exposed
Wastewater exposure				
Memphis	Cosxackie A9	10/78	.029	Inexperienced sewage-exposed
Memphis	Adenovirus	10/78	.040	Inexperienced sewage-exposed

*Workers with high exposure compared with those with low exposure.

**Inexperienced workers with high exposure compared with controls with low exposure.

Because the exposed or higher exposed group had higher titer levels in nine of the 10 cases where $p \leq .05$, these comparisons suggest a possible wastewater effect. However, the total number of differences is much less than expected by chance. In addition, it has previously been shown that the Memphis inexperienced sewage treatment plant workers had higher titers to Coxsackie A9 virus, for which two of the 10 differences occurred, when they started work.

Combined city comparison--Inexperienced sewage-exposed workers in the three cities were combined for comparison with the combined control group. Results from the second phase of the virus serology survey were compared between subgroups of the inexperienced sewage-exposed workers subdivided according to exposure to liquid/solids and aerosols as previously described. In addition, comparisons were made between the high exposed sewage workers and the low exposed control workers. There were 13 comparisons of 204 (17 viruses x two exposures x six comparisons) where $p \leq .05$; five from the inexperienced worker comparisons and eight from the inexperienced/control comparisons (Table 71). Of the comparisons involving only inexperienced sewage workers, four are in a direction consistent with a sewage effect and are equally divided between aerosol and wastewater comparisons. Six of the eight comparisons of inexperienced wastewater and control workers involved higher levels among the wastewater workers; four of which were of wastewater/sludge exposures.

Again for these comparisons in 10 of the 13 situations where $p \leq .05$, the higher exposed group had the higher titer levels. Of these 10 significant comparisons, six involved liquid/solids exposure and four airborne bacteria exposure.

Length of Exposure Effect--

Including the experienced sewer maintenance and experienced sewage treatment plant workers in Cincinnati in the study provided the opportunity to measure the effect, if any, of length of wastewater exposure on prevalence of antibody to viruses tested. Using the serology data from January 1978 sera, prevalence was tested at the ≥ 2 titer level. Average length of time on the job in days was calculated for those workers with and without antibody at each of these two levels. Thirty-four comparisons were made, 17 viruses and two groups for each. Five of the 34 comparisons were significant ($p \leq .05$) (Table 72). (Significance levels for all the comparisons are presented in Appendix J.) Three involved experienced sewer maintenance workers and two experienced sewage treatment plant workers. For four of the five comparisons, the average length of time on the job for the subgroup *with* antibody was less than that for the subgroup *without* antibody.

Hepatitis A--

Antibody to Hepatitis A (anti-HAV) was determined twice during the study. The first testing was performed by the Center for Disease Control (CDC) on paired sera collected from Cincinnati workers. The first sera of the pair was the initial one collected from the volunteer and the second was collected in April 1977 or the serum collected closest to that date as possible. The second testing was performed by the University of Cincinnati (UC) on a single

TABLE 71. SUMMARY OF COMPARISON OF EXPOSURE AND SEROLOGY DATA FOR COMBINED THREE-CITY INEXPERIENCED SEWAGE WORKER AND CONTROL WORKER GROUP* ($p \leq .05$)

Workers with higher titers	Worker group compared*	Date	Environment parameter	Virus	Significance (p)
High exposed	Inexperienced sewage-exposed	January 1978	Liquid/solids	Polio 1	.022
High exposed	Inexperienced sewage-exposed	January 1978	Liquid/solids	Adenovirus	.003
Inexperienced sewage-exposed	Inexperienced sewage-exposed/ control	January 1978	Liquid/solids	Polio 1	.019
Inexperienced sewage-exposed	Inexperienced sewage-exposed/ control	October 1978	Liquid/solids	Coxsackie A9	.046
Inexperienced sewage-exposed	Inexperienced sewage-exposed/ control	October 1978	Liquid/solids	Coxsackie B3	.036
Inexperienced sewage-exposed	Inexperienced sewage-exposed/ control	October 1978	Liquid/solids	Adenoviurs	.049
Control	Inexperienced sewage-exposed/ control	October 1978	Liquid/solids	Echo 8	.035
High exposed	Inexperienced sewage-exposed	January 1978	Air	Coxsackie B1	.046
High exposed	Inexperienced sewage-exposed	January 1978	Air	Echo 21	.033

(continued)

TABLE 71 (continued)

Workers with higher titers	Worker group compared*	Date	Environment parameter	Virus	Significance (p)
Inexperienced sewage-exposed	inexperienced sewage-exposed/ control	January 1978	Air	Echo 6	.034
Control	Inexperienced sewage-exposed/ control	January 1978	Air	Herpes Simplex	.023
Inexperienced sewage-exposed	Inexperienced sewage-exposed/ control	October 1978	Air	Coxsackie B3	.017
More 4-fold greater increases in lower exposed	Inexperienced sewage-exposed	January 1978 & October 1978	Air	Coxsackie B5	.045

*Number of workers:

	Inexperienced sewage worker		Control	
	Liquid/solids	Air	Liquid/solids	Air
Above average exposure	62	52	52	45
Average or below average exposure	48	58	63	70

TABLE 72. PREVALENCE OF ANTIBODY AND LENGTH OF TIME ON JOB - LIST OF SIGNIFICANT COMPARISONS ($p \leq .05$) FOR EXPERIENCED SEWER MAINTENANCE AND EXPERIENCED SEWAGE TREATMENT PLANT WORKERS

Virus	Worker group	Negative or positive*	Average length of time on job (days)	Number of workers
Polio 2	Experienced sewer maintenance	Positive	3340	37
Polio 2	Experienced sewer maintenance	Negative	7925	1
Polio 3	Experienced sewer maintenance	Positive	3159	33
Polio 3	Experienced sewer maintenance	Negative	5446	5
Coxsackie B3	Experienced sewer maintenance	Positive	2944	25
Coxsackie B3	Experienced sewer maintenance	Negative	4312	14
Polio 1	Experienced sewage treatment	Positive	2381	36
Polio 1	Experienced sewage treatment	Negative	6442	3
Echo 8	Experienced sewage treatment	Positive	6456	2
Echo 8	Experienced sewage treatment	Negative	2516	38

*Test results from January 1978 sera used, positive denotes titer level ≥ 2.

specimen of sera collected as close as possible to July 1978 from study volunteers in all three cities. Although the test methods were the same in both cases the CDC results were expressed in numerical units while the UC test results were reported only as positive or negative. The CDC results could, therefore, be analyzed differently. The results of both tests will be discussed separately and then together.

CDC Testing--Two separate serum samples were obtained in Cincinnati from each of 86 sewage-exposed workers and 25 highway maintenance workers. The pairs of sera were collected at varying times over a two-year period, with the interval between samples ranging from one to 24 months. The inexperienced sewage-exposed workers included both those engaged in sewer maintenance and those working at sewage treatment plants and consisted of those entering the study shortly after becoming employed in the sewage occupation. The experienced workers in each group were those employed for more than one year at the time of joining the study. All subjects were male and ages ranged from 19 to 44.

The sera were analyzed for anti-HAV by solid-phase, double-antibody radioimmunoassay by the Hepatitis Laboratories Division of the U.S. Center for Disease Control at Phoenix, Arizona. Results were expressed as P/N ratios, with P being the counts per minute and N the average value of sera known to be negative. Ratios of 2.1 and greater were considered to be positive.

Several concomitant variables were taken into account, namely, age, race, length of time on the job, length of time between samples, and socioeconomic status (SES) factors of education, household income, and family size. Since the P/N is a ratio with N constant, the P/N values were distributed as the P values. This distribution was found to be approximately log-normal. Those data reported as <2 were assigned a value of 1, and those reported as <1 assigned a value of 0.5. The data were then log-transformed so that classical statistical procedures could be used. Analysis of covariance was used for each sample separately to look for differences among worker groups, followed by Scheffé contrasts (30). Differences between first and second samples for each worker group were examined by multiple regression followed by Tukey's test for nonadditivity to test for the consistence of differences among the workers in each worker group.

Statistical analyses of the P/N ratios for the work groups (Table 73) revealed that the experienced sewer maintenance workers had significantly ($p \leq .02$) lower levels of anti-HAV than did either highway maintenance workers or inexperienced sewage-exposed workers. Age and race are both significant covariants, with antibody increasing with age, and with black workers having higher levels than whites. None of the other covariants were significant. For the inexperienced workers, the first sample was taken as they started work in a sewage-exposed environment, and the second sample after an interval of exposure that ranged from one to twenty-four months.

A significant increase from the first sample to the second occurred only in the experienced sewage treatment plant workers (Table 74). Tukey's test for nonadditivity was not significant; that is, the increases were consistent. None of the covariants were significant.

TABLE 73. COMPARISON OF ANTI-HAV TEST RESULTS IN CINCINNATI WORKERS

ISE = Inexperienced Sewage-Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Plant Workers
HM = Highway Maintenance Workers

Cincinnati

	First Sample	Second Sample
Significance of Difference Among Groups	.002	.025
Significance of Age	.001	.001
Significance of Race	.002	.009

Geometric Means

Group	First Sample			Second Sample		
	N	Number Positive*	Geometric Mean of P/N	N	Number Positive*	Geometric Mean of P/N
ISE	23	7	1.68[a]	23	7	1.68[c]
ESM	33	9	1.15[a,b]	31[†]	11	1.38[c,d]
EST	28[+]	5	1.38	30	7	1.51
HM	25	14	2.56[b]	25	15	2.83[d]

[a,b,c,d] Pairs of numbers with the same letter are significantly different by Scheffé contrast (p < .02).

*P/N >2.1 where P is the counts per minute of the sample and N is the average counts per minute of sera known to be negative.

[†] For two workers the test did not produce usable results.

TABLE 74. STATISTICAL COMPARISON OF DIFFERENCES BETWEEN HEPATITIS A VIRUS ANTIBODY MEASUREMENTS FOR FIRST AND SECOND SERUM SAMPLES

ISE = Inexperienced Sewer Maintenance and Sewage Treatment Plant Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Plant Workers
HM = Highway Maintenance Workers

Differences Between First and Second Sample

	Group	N	t-Statistic	Significance
Cincinnati	ISE	19	.990	.30
	ESM	30	1.280	.25
	EST	28	2.838	.009
	HM	19	.262	.80

The results from our study in Cincinnati appear to confirm previous findings that anti-HAV increases with age (28,29). In addition, we have found that blacks have significantly higher anti-HAV levels than whites. Since the SES of all groups is similar, it appears that the variation with race is independent of SES. The SES factors of education, household income, and family size were not significant covariants. Although higher levels were found in black subjects than in whites in other studies (28,31), this was thought to be a result of SES rather than race.

The only group showing an increase from the first sample to the second greater than would be expected on the basis of increased age was the experienced sewage treatment plant workers. Overall, the experienced sewage treatment plant workers had lower levels than the others. The group having the highest levels (inexperienced sewage-exposed) had not been exposed to sewage at the time the first sample was collected and did not show a change from the first to the second sample. Since the samples were taken over a two-year period, there may be a seasonal pattern which would not be apparent from our data.

University of Cincinnati testing--Results of analysis of sera collected during the July 1978 quarters are shown in Tables 75-77 for Cincinnati, Chicago and Memphis, respectively. In Cincinnati, the highway maintenance and experienced sewer maintenance groups had more positive values than expected and the experienced sewage treatment and inexperienced sewage-exposed groups had fewer than expected ($p < .001$). There were no significant differences between the Chicago groups. In Memphis, the Memphis Light, Gas and Water workers had more positive values than expected and the sewage treatment plant workers had fewer. The differences in both Cincinnati and Memphis may be due at least in part to age differences between the groups.

Combined data--Table 78(a) indicates the number of workers who tested positive on either the CDC or UC testing divided by the number of workers tested. There is a difference ($p < .001$) between the results for the Cincinnati groups. The sewer and highway maintenance groups have a higher than expected number of positive results and the two groups of sewage treatment plant workers have lower than expected numbers of positive results.

There were a total of 81 people in all three cities who were tested at least twice and whose first test had a negative result. An examination of the number of people in this group whose subsequent sera was analyzed to be positive is shown in Table 78(b). There was no significant difference in the rate of seroconversion between the exposed and nonexposed groups.

Based on testing to date there is no indication that exposure to sewage increases the prevalence of anti-HAV. However, it should be cautioned that only selected sera have been analyzed. In a number of cases, initial sera have not been analyzed and thus no indication is available concerning the anti-HAV status at the start of the study. Additional analyses will have to be performed before further conclusions can be reached.

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TABLE 75. RESULTS OF TESTING FOR HEPATITIS A ANTIBODY CINCINNATI JULY 1978 SERA

Work Group	Positive	Negative	
Inexperienced Sewage-Exposed - 1st & 2nd Sera	7	11	18
Inexperienced Sewage-Exposed - Later Sera	13	23	36
Experienced Sewer Maintenance	37	19	56
Experienced Sewage Treatment	24	33	57
Highway Maintenance	55	19	74
	136	105	241

p <.001

TABLE 76. RESULTS OF TESTING FOR HEPATITIS A ANTIBODY CHICAGO JULY 1978 SERA

Work Group	Positive	Negative	
Inexperienced Sewage Treatment Plant - 1st or 2nd Sera	3	3	6
Inexperienced Sewage Treatment Plant - 3rd or Later Sera	14	25	39
Experienced Sewage Treatment Plant	16	15	31
Waterworks	22	14	36
	55	57	112

p = .11

TABLE 77. RESULTS OF TESTING FOR HEPATITIS A ANTIBODY MEMPHIS JULY 1978 SERA

Work Group	Positive	Negative	
Inexperienced Sewage Treatment Plant - 1st & 2nd Sera	5	9	14
Inexperienced Sewage Treatment Plant - Later Sera	2	29	31
Memphis Light, Gas and Water	21	34	55
	28	72	100

$p < .01$

TABLE 78. CENTER FOR DISEASE CONTROL (CDC) AND UNIVERSITY OF CINCINNATI (UC) HEPATITIS A TESTING

a.

	Number of Positive CDC OR UC Number of Workers Tested
Cincinnati	
Inexperienced Sewer Maintenance	7/12
Inexperienced Sewage Treatment	16/43
Experienced Sewer Maintenance	40/60
Experienced Sewage Treatment	26/59
Highway Maintenance	57/77
	$p < .001$
Chicago	
Inexperienced Sewage Treatment	19/52
Experienced Sewage Treatment	18/34
Water Works	25/46
	$p = .260$
Memphis	
Inexperienced Sewage Treatment	7/45
Experienced Sewage Treatment	6/15
Memphis Light, Gas and Water	20/54
	$p = .040$

b.

	Number of Persons Negative on 1st Specimen Tested	Number of Persons in Column (a) "Positive on 2nd or 3rd Specimen
Exposed	63	11
Non-Exposed	18	4
		$p = 0.648$

Hepatitis B--

Hepatitis B antibody and antigen determinations have been made since October 1975 for Cincinnati workers, since July 1976 for Chicago workers and only in 1978 for Memphis workers. Antigen determinations have been negative except for four workers. Three were employed in Cincinnati: an inexperienced sewer maintenance worker, an experienced sewage treatment plant worker and a highway maintenance worker. The fourth was a MLG&W worker in Memphis.

Hepatitis B antibody levels have never been significantly different between groups within any of the study cities. 1975-1976 results for Cincinnati appear in Table 79, 1976-1977 Chicago results in Table 80, January 1978 results for all three cities in Table 81 and October 1978 results for all three cities in Table 82.

Another important comparison is the number of workers whose test results change from negative for the antibody to positive during the course of the study. Workers whose sera was tested in at least two different quarters and for whom the first result was negative were defined as susceptible for seroconversion. Seroconverters were defined as those susceptible whose sera from a later quarter tested positive. All positive results were retested for confirmation. A tabulation of Hepatitis B seroconversion results (Table 83) revealed that eight of the 10 seroconversions were from Cincinnati workers. The number of Cincinnati workers susceptible to seroconversion was greater than that in the other two cities combined and they were in the study for longer periods of time. Comparing the combined exposed groups in Cincinnati with the Cincinnati control workers (Table 84) did not reveal a significant difference in rates of seroconversion.

In conclusion, no evidence was found for an increase in Hepatitis B infections among wastewater exposed individuals.

Family Study--

Six viruses were included in the analyses of the serum of workers and their family members. Results for workers in the inexperienced sewage-exposed groups, experienced sewage treatment groups, and control groups were compared with results from serum collected from their household members at or about the same time, July 1978. These sera were analyzed for antibodies to Polio 1, 2, 3, Echo 9, Coxsackie A9, and Hepatitis A. Table 85 indicates the number of families by group and by city. Because of the limited number of sera, participants from the three cities were combined for the statistical analysis.

Household members were categorized as "other adult" or "child," (18 or under). For each household, the geometric mean titer level was calculated for all "other adults" and for all "children," in order to have one value for each category representing each household.

First, comparisons among the three categories were performed, with results given in Table 86. Five comparisons were significant at $p \leq .01$ and an additional two at $p \leq .05$. For Polio 1, the children of experienced sewage-exposed workers had lower antibody levels ($p = .006$) than the other adults who were higher than the workers. For Polio 2, children of control workers had

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TABLE 79. HEPATITIS B ANTIBODY RESULTS FOR CINCINNATI WORKERS 1975 - 1977

ISE = Inexperienced Sewage Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Workers
HM = Highway Maintenance Workers

		Number of Workers Antibody Test Results		
Sera Date	Work Group	Positive	Negative	p value
Oct., 1975	ESM	9	36	.695
	HM	8	41	
Apr., 1976	ESM	9	38	.880
	HM	11	50	
Oct., 1976	ESM	9	30	.902
	EST	10	41	
	HM	11	43	
Apr., 1977	ISE	5	9	.210
	ESM	9	24	
	EST	6	36	
	HM	9	34	
Oct., 1977	ISE	6	25	.850
	ESM	7	33	
	EST	5	35	
	HM	7	42	

TABLE 80. HEPATITIS B ANTIBODY RESULTS FOR CHICAGO WORKERS 1976 - 1977

IST = Inexperienced Sewage Treatment Workers
EST = Experienced Sewage Treatment Workers
WT = Water Treatment Workers

		Number of Workers		
		Antibody Test Results		
Sera Date	Work Group	Positive	Negative	p value
July, 1976	IST	4	17	.569
	EST	1	14	
Nov., 1976	IST	5	20	.147
	EST	1	27	
Oct., 1977	IST	6	25	.052
	EST	0	33	
	WT	5	18	

TABLE 81. HEPATITIS B ANTIBODY RESULTS FOR WORKERS IN THREE STUDY CITIES JAN. 1978 SERA

Numbers of workers with specified test results

Cincinnati

	Test Results	
	Positive	Negative
Inexperienced Sewage Exposed	5	18
Experienced Sewer Maintenance	9	23
Experienced Sewage Treatment Plant	7	29
Highway Maintenance	5	34

p = .488

Chicago

	Test Results	
	Positive	Negative
Inexperienced Sewage Treatment Plant	8	34
Water Works	1	14

p = .474

Memphis

	Test Results	
	Positive	Negative
Inexperienced Sewage Treatment Plant	5	27
Memphis Light, Gas & Water	8	38

p = .862

TABLE 82. HEPATITIS B ANTIBODY RESULTS FOR WORKERS IN THREE STUDY CITIES. OCT. 1978 SERA

Numbers of workers with specified test results

Cincinnati

	Test Results Positive	 Negative
Inexperienced Sewage Exposed	5	21
Experienced Sewer Maintenance	7	28
Experienced Sewage Treatment Plant	6	36
Highway Maintenance	7	27

p =.877

Chicago

	Test Results Positive	 Negative
Inexperienced Sewage Treatment Plant	7	30
Water Works	2	19

p = .567

Memphis

	Test Results Positive	 Negative
Inexperienced Sewage Treatment Plant	5	28
Memphis Light, Gas and Water	8	32

p = .600

TABLE 83. WORK GROUP OF PERSONS SEROCONVERTING TO HEPATITIS B DURING COURSE OF STUDY

Work Group	No. Seroconversions	Size of Eligible Group*
Cincinnati		
Inexperienced Sewer Maintenance	2	10
Inexperienced Sewage Treatment	0	28
Experienced Sewer Maintenance	3	44
Experienced Sewage Treatment Plant	2	41
Highway Maintenance	1	52
Chicago		
Inexperienced Sewage Treatment	1	38
Experienced Sewage Treatment	0	35
Water Treatment	0	21
Memphis		
Inexperienced Sewage Treatment	0	23
Light, Gas and Water	1	31

* Defined as number of workers tested at least twice during the study where first specimen tested negative.

TABLE 84. COMPARISON OF SEROCONVERSION TO HEPATITIS B IN COMBINED SEWAGE-EXPOSED WORKERS WITH CONTROL WORKERS IN CINCINNATI

Worker group	Number susceptible to seroconversion	Number seroconversion
Sewage-exposed	123	7
Control	52	1

p = .515 (chi-square)

TABLE 85. FAMILY STUDY - SUBJECT COMPOSITION

Number of Families Included in Study

	City			
Work group	Cincinnati	Chicago	Memphis	Total
Inexperienced sewage-exposed	13	14	14	41
Experienced sewage treatment	23	18	0	41
Control	12	11	18	41
Total	48	43	32	123

Family Combinations

	Worker-other adult(s) child(ren)	Worker-other adult(s)	Worker-child(ren)	Total
Inexperienced sewage-exposed	21	19	0	40
Experienced sewage treatment	22	19	0	41
Control	26	14	1	41
Total	69	52	1	122

TABLE 86. WITHIN-FAMILY* COMPARISONS OF VIRUS ANTIBODY TITER LEVELS FOR FAMILIES THAT INCLUDE OTHER ADULTS AND CHILDREN

ISE = Inexperienced Sewage Exposed Workers
EST = Experienced Sewage Treatment Plant Workers

Family group	Virus	Geometric Mean Titer Level Worker	Other adult(s)	Child(ren)	Significance level
ISE	Polio 1	23.8	28.8	12.7	.082
EST	Polio 1	14.6	30.5	10.3	.006
Control	Polio 1	11.9	21.3	10.3	.103
ISE	Polio 2	13.1	15.1	12.4	.829
EST	Polio 2	20.1	10.0	12.0	.134
Control	Polio 2	22.0	24.6	9.6	.003
ISE	Polio 3	8.5	16.6	5.6	.049
EST	Polio 3	6.4	10.2	5.7	.167
Control	Polio 3	9.9	15.3	6.1	.087
ISE	Echo 9	2.4	3.2	3.8	.483
EST	Echo 9	2.7	6.0	3.2	.081
Control	Echo 9	2.5	3.1	5.0	.104
ISE	Coxsackie A9	3.1	3.0	2.8	.891
EST	Coxsackie A9	2.7	3.8	3.4	.347
Control	Coxsackie A9	3.2	3.8	2.7	.422
ISE	Hepatitis A**	2.5	2.4	2.0	.0001
EST	Hepatitis A	2.5	2.2	2.1	.0072
Control	Hepatitis A	2.5	2.3	2.0	.0001

*Number of families that include other adults and children: ISE 21; EST 22; and control 26.

**Hepatitis A results reported as "positive" or "negative." Negative was assigned a value of 2, positive a value of 3.

lower levels ($p = .003$) than the workers who were somewhat lower than the other adults. For Hepatitis A the workers in all three groups had higher levels than children (p ranged from .001 to .0072) and to a lesser degree were higher than other adults.

Comparisons were also done in pairs: worker-other adult, worker-children, and worker-other household members. There were 10 comparisons where $p \leq .05$ (Table 87). There were no significant differences between workers and other adults ($p \leq .01$). For the other two types of comparisons, only results for Hepatitis A were significant at p .01. The differences in all cases are attributable to higher levels among the workers than the children. The worker levels are not significantly higher than those of other adults in the household, so these differences are likely due to age. The significant differences ($p \leq .01$) for the inexperienced workers for Polio 1 and for controls for Polio 2 are no longer apparent (but are relevant at $p = .02$ and .03) when the group size is increased or when other household members are combined.

Bacterial Serology

Salmonella Serology--

Antibodies to Salmonella A, B, C, D and E were measured several times during the study beginning in 1975. The first testing was performed on sera collected from sewer maintenance and highway maintenance workers in Cincinnati during July and October 1975 and April 1976 using the rapid slide agglutination method. No differences were found in prevalence levels or in titer level changes.

Groups of 30 age matched workers were tested by the passive hemagglutination method in 1976 (Cincinnati) and 1977 (Chicago). The age composition of the workers in the groups is given in Table 88. Only one difference between groups was detected ($p \leq .05$). The water treatment workers had slightly higher titer levels than the inexperienced sewage treatment plant workers in October 1977 (Table 89).

The final testing included sera for inexperienced workers. Worker groups tested were the inexperienced sewage-exposed and control groups in each city plus the experienced sewer maintenance and experienced sewage treatment plant workers in Cincinnati. No significant differences ($p \leq .01$) were found in either prevalence in January and October 1978 or titer level changes between these two for Cincinnati, Chicago, or Memphis but there were four comparisons where $p \leq .05$ (Table 90).

For Chicago, Salmonella C antibody levels were somewhat higher in the inexperienced sewage treatment plant workers than in the water works employees ($p = .047$) in October 1978. In Memphis the inexperienced sewage treatment plant workers were somewhat higher than Memphis Light, Gas and Water workers for the same antibody in January 1978 ($p = .012$) and for Salmonella D antibodies in October 1978 ($p = .049$). There also were somewhat higher numbers of titer level increases ($p = .030$) in Salmonella D antibody in the inexperienced

TABLE 87. SUMMARY OF SIGNIFICANT ($p \le .05$) COMPARISON INCLUDING WORKERS AND OTHER GROUPS OF HOUSEHOLD MEMBERS

Inexperienced workers	p	Groups compared (geometric mean*)	
Hepatitis A	<.001	Workers (2.5)	Children (2.0)
Experienced workers			
Polio 1	.022	Workers (32)	Other adults (49)
Hepatitis A	<.001	Workers (2.6)	Children (2.1)
Hepatitis A	<.001	Workers (2.5)	Other household members (2.1)
Controls			
Polio 1	.029	Workers (29)	Other adults (48)
Polio 2	.023	Workers (35)	Children (14)
Echo 9	.033	Workers (4)	Children (10)
Hepatitis A	<.001	Workers (2.5)	Children (2.0)
Hepatitis A	<.001	Workers (2.5)	Other household members (2.2)

*Geometric mean titer level. For Hepatitis A a positive result was assigned a value of 3 and a negative result a value of 2.

TABLE 88. AGE COMPOSITION OF WORKER GROUPS TESTED IN 1976 and 1977 BACTERIAL SEROLOGY

Cincinnati

	21-25	26-30	31-40	41-50	51-60	Total
Experienced Sewer Maintenance	3	5	8	8	6	30
Experienced Highway Maintenance	1	4	8	11	6	30
Experienced Sewage Treatment	3	5	8	8	6	30
Total	7	14	24	27	18	90

Chicago

	31-40	41-50	51-60	Over 60	Total
Experienced Sewage Treatment	6	6	12	6	30
Water Treatment	4	8	14	4	30
Total	10	14	26	10	60

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TABLE 89. SALMONELLA ANTIBODY COMPARISON WHERE p = _ .05
CINCINNATI AND CHICAGO AGE-MATCHED GROUPS, 1976, 1977

Group test and data	Titer levels								p	Geometric mean
	<2	2	4	8	16	32	64	≥128		
Chicago										
Salmonella A 10/76									.044	
Inexperienced sewage-exposed	5	4	0	2	2	1	0	0		3.1
Control	0	9	4	4	1	1	0	0		4.0

TABLE 90. SUMMARY OF SALMONELLA ANTIBODY COMPARISONS WHERE p _ .05
FINAL TESTING, ALL CITIES, 1978

Group test and data	Titer levels								p	Geometric mean
	2	2	4	8	16	32	64	≥128		
Chicago										
Salmonella C 10/78									.047	
Inexperienced sewage-exposed		2	0	10	22	9	2	1		16.0
Control		1	6	7	6	7	0	0		10.9
Memphis										
Salmonella C 1/78									.012	
Inexperienced sewage-exposed		0	2	16	14	6	1	2		14.5
Control		4	9	10	11	12	4	0		12.1
Salmonella D 10/78									.049	
Inexperienced sewage-exposed		0	1	7	3	4	14	12		43.4
Control		0	5	7	12	8	11	6		24.8
Salmonella D 1-10/78									.030	
	Titer Level Changes									
	-1	0	+1	+2	+3	+4	+5	+6		
Inexperienced sewage-exposed	11	14	10	2	3	0	0	1		5.2
Control	12	30	6	0	0	0	0	0		3.7

Memphis sewage treatment plant workers during the January-October 1978 period. These latter two comparisons are consistent with an infection with Salmonella D during the January-October 1978 period.

Comparison of Salmonella antibody levels in first sera collected from inexperienced sewage-exposed workers with the levels in January 1978 did not reveal any differences ($p \leq .05$).

Age-race exposure effects--In order to determine if Salmonella antibody levels were affected by age, race, liquid/solids, and aerosol exposure, the results of testing of January 1978 and October 1978 sera were compared to these factors. For each group in each city, workers were divided by race, those above the average age and those at or below average age, and similarly for the two exposure categories. For inexperienced sewage-exposed workers, experienced sewer maintenance and experienced sewage treatment workers in Cincinnati, no differences ($p \leq .05$) were found for any of these factors. For the highway maintenance workers in Cincinnati those with low exposure to aerosols and liquid/solids had higher levels of antibody to Salmonella B ($p = .031$ and .012, respectively). In Chicago, no differences were found in the control workers but the older inexperienced sewage treatment plant workers had higher levels of antibody to Salmonella A and B ($p = .037$ and .036, respectively). During the January-October 1978 period for inexperienced sewage treatment plant workers in Memphis there were more increases in antibody levels to Salmonella D in the younger workers ($p = .028$) and more decreases in white workers ($p = .035$). Thus the apparent infection with Salmonella D previously found for this group appear to have been in the younger black workers. Comparisons of the high exposure exposed groups with the lower exposure control groups did not reveal any differences ($p \leq .05$) in any of the cities.

Summary of Salmonella serology--A summary of all comparisons including Salmonella antibody levels (Table 91) shows a total of 705 comparisons performed, 315 of which involved age, race or comparisons within control groups. Of the remaining 390, only five were significant at $p \leq .05$. In four a wastewater-exposed group had higher levels. These findings suggest a slight risk of bacterial infections among wastewater workers was significant at $p \leq .05$.

Leptospira--

Twice during the study 20 leptospiral agglutinins were measured by a standard microtiter technique at the Leptospirosis Reference Laboratory of the Center for Disease Control in Atlanta. On both occasions only single blood specimens from study participants were tested. The first testing involved the following groups of Cincinnati workers:

Inexperienced Sewage-Exposed	10
Experienced Sewer Maintenance	47
Experienced Highway Maintenance	67

The specimens used in this testing were those collected during the July 1977 quarter, if available. Otherwise the next earlier specimen was analyzed. For the inexperienced workers in most cases the blood specimens analyzed were

TABLE 91. SUMMARY OF SIGNIFICANT ($p \leq .05$) COMPARISONS OF SALMONELLA SEROLOGY RESULTS FOR GROUPS IN CINCINNATI, CHICAGO AND MEMPHIS, ALL YEARS

1975

30 comparisons
(2 groups x 5 bacteria x 3 procedures)
No significant difference

1976-77

75 comparisons
(5 groups x 5 bacteria x 3 procedures)
One test $\leq$ 0.05
Chicago October 1976 Salmonella A (p = .044) (control higher)

1978 and first sera for inexperienced workers

Group comparisons - 45 comparisons
(5 bacteria x 3 procedures x 3 cities)
4 tests $\leq$ .05
Chicago 10/78 Salmonella C (p = .047, inexperienced sewage-exposed higher
Memphis 1/78 Salmonella C (p = .012, inexperienced sewage-exposed higher
10/78 Salmonella D (p = .049, inexperienced sewage-exposed higher
1/78-10/78 Salmonella D (p = .030, more inexperienced sewage-exposed increases

Aerosols - 90 comparisons (within groups)
(5 bacteria x 6 groups x 3 procedures)
One test $\leq$ .05
Cincinnati control 10/78 Salmonella B (p = .031, low exposed higher)

Inexperienced - comparison of first blood with 1/78 15 comparisons
(5 bacteria x 3 cities)
No significant difference ($p \leq .05$)

(continued)

TABLE 91 (continued)

Liquid/solids - 120 comparisons (within groups)

(5 bacteria x 8 groups x 3 procedures)

One test $\leq .05$

Cincinnati control 10/78 Salmonella B ($p = .012$, low exposed higher)

January 1978 and October 1978 comparisons

Group comparisons

1978 and first sera for inexperienced workers

Aerosols - high exposure study group/low exposure controls 45 comparisons

(5 bacteria x 3 procedures x 3 cities)

No significant difference ($p \leq .05$)

Liquid/solids - high exposure study group/low exposure controls 45 comparisons

(5 bacteria x 3 procedures x 3 cities)

No significant difference ($p \leq .05$)

Age - 120 comparisons

(5 bacteria x 8 groups x 3 procedures)

3 tests $\leq .05$

Chicago inexperienced sewage-exposed 1/78 Salmonella A ($p = .037$, older higher)

1/78 Salmonella B ($p = .028$, older higher)

Memphis inexperienced sewage-exposed 1/78-10/78 Salmonella D ($p = .028$, more increases younger)

Race - 120 comparisons

5 bacteria x 8 groups x 3 procedures)

One test $\leq .05$

Memphis inexperienced sewage-exposed 1/78-10/78 Salmonella D ($p = .035$, more decreases white)

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collected about 18 months after exposure began. For one worker the time period was nine months. Twenty-five workers (18 highway maintenance workers) had antibody to one Leptospira antigen, and one highway worker had antibody to two antigens. Three inexperienced and four experienced sewage-exposed workers had antibody to a single Leptospira. Results are presented in Table 92. More nonexposed workers (highway maintenance workers) had antibodies to one or more antigens than did sewage-exposed workers ($p = .049$).

The second Leptospira serosurvey was performed on specimens collected in the July 1978 quarter or the latest available specimen after July 1977, from workers in all three cities. For inexperienced sewage-exposed workers only those who were employed a minimum of six months or more at the time of testing were included. The total number of workers included in the testing was as follows:

Cincinnati:

Inexperienced Sewage-Exposed	32
Experienced Sewer Maintenance	55
Experienced Sewage Treatment	49
Highway Maintenance	68

Chicago:

Inexperienced Sewage Treatment	31
Experienced Sewage Treatment	23
Water Works	27

Memphis:

Inexperienced Sewage Treatment	26
Memphis Light, Gas and Water	37

All sera from Cincinnati workers were negative. Four exposed workers (inexperienced) and one control worker in Chicago had antibody to one of the Leptospira. In Memphis, five of the inexperienced workers had antibody to one Leptospira and two had antibody to two but no one in the other groups had any antibody in detectable amounts. Because of the low number of positive values, all three cities are combined in Table 92. A higher percent of exposed workers had antibody to at least one Leptospira ($p = 0.041$). There was no significant ($p \leq .05$) difference between the groups.

Summary--The results of the leptospiral survey did not provide evidence of an increased risk of infection among sewage-exposed workers. In one year more nonexposed workers showed presence of antibody and in the other year the opposite, although not at $p \leq .05$.

Legionnaires Disease--

Antibody to Legionella pneumophila was determined on sera collected from all study groups during the July 1978 quarter. For inexperienced sewage-exposed workers, data were separated into those for whom their first or second

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TABLE 92. LEPTOSPIRA SURVEY* OF CINCINNATI WORKERS (JULY 1977 OR EARLIER SPECIMENS)

	Number with antibody to one or more leptospira	Number with no antibody
Sewage-exposed workers (57)	7	50
Nonexposed workers (67)	19	48
	p = .049 (chi-square)	

*Analyses performed by Leptospirosis Reference Laboratory of the Center for Disease Control.

TABLE 93. LEPTOSPIRA SURVEY* OF SEWAGE-EXPOSED AND NONSEWAGE-EXPOSED WORKERS IN CINCINNATI, CHICAGO, AND MEMPHIS (JULY 1978 SERA OR LATEST AVAILABLE AFTER JULY 1977 USED FOR ANALYSIS)

	Number with antibody to one or more leptospira	Number with no antibody
Sewage-exposed workers (225)	11	214
Nonexposed workers (132)	1	131
	p = .065 (chi-square)	

*Analyses performed by Leptospirosis Reference Laboratory of the Center for Disease Control in Atlanta.

serum specimen was used, and those for whom a later specimen was used. No significant differences were found between groups in any of the cities (Table 94). Of the total 497 workers tested, 65 percent had a titer level of <64, 21 percent had a titer level of 64, and 14 percent had a titer level of ≥ 128.

Immunoglobulins and Rheumatoid Factor

Immunoglobulins IgA, IgM and IgG were determined for Cincinnati workers in sera collected during July 1975 and July 1976; for Chicago workers in January 1977 sera; and for workers from all three cities in January and October 1978 sera. In addition first and second sera were also analyzed for the inexperienced sewage-exposed workers.

Cincinnati - 1975 and 1976--

Levels of IgG, IgA, and IgM were measured in sera obtained from sewer maintenance, highway maintenance, and sewage treatment workers. Levels of IgG in highway workers were significantly higher than those in the sewer workers during both years (Table 95). No consistent differences in IgA or IgM levels were observed when the sewer and highway maintenance groups were compared. The difference in IgM levels observed in 1975 were not evident in 1976. Since IgM levels increase in response to an infection and later decrease, the sewage maintenance workers may have been experiencing an infection as a group in July 1975. IgM levels were found to be lower in both groups during the second year. IgA levels in the experienced sewage treatment workers were significantly lower than that of the experienced sewer maintenance group. In contrast, IgG and IgM levels in this group were not significantly different from the other two groups.

Chicago - 1977--

No significant differences were found between immunoglobulin levels in January 1977 sera collected from inexperienced sewage treatment plant workers, experienced sewage treatment plant workers and waterworks employees (Table 96).

Cincinnati - 1978--

IgG levels were significantly lower in the experienced sewage treatment plant workers ($p < .001$) for both January and October 1978 (Table 97). Experienced sewer maintenance workers were highest in January and inexperienced sewage-exposed workers highest in October. IgA levels were highest in highway maintenance workers during both times and significantly so ($p < .017$) during October. Changes in IgA values were significantly different between January and October ($p = .001$) with highway maintenance workers and experienced sewage treatment plant workers both increased while the other two groups decreased slightly. All four groups decreased in IgG levels from January to October ($p = .001$) with experienced sewer maintenance workers and highway maintenance workers decreasing the most. There does not appear to be any consistent increase in Ig levels among the sewage-exposed workers. The elevation of IgG in highway maintenance workers in 1975 and 1976 was not evident in 1978.

TABLE 94. COMPARISON OF TITER LEVELS TO LEGIONELLA PNEUMOPHILA IN CINCINNATI, CHICAGO AND MEMPHIS WORKER GROUPS - JULY 1978

Worker group	Total no. of workers	Number (percent) of workers with specified titer levels		
		≤64	64	≥128
Cincinnati				
Inexperienced sewage-exposed (1st and 2nd specimen)	22	15(68)	5(23)	2(9)
Inexperienced sewage-exposed (3rd and later specimen)	33	23(70)	4(12)	6(26)
Experienced sewer maintenance	59	33(56)	14(25)	11(19)
Experienced sewage treatment	58	46(79)	7(12)	5(9)
Highway maintenance	77	45(58)	16(21)	16(21)
			p = .056	
Chicago				
Inexperienced sewage treatment (1st and 2nd specimen)	11	9(82)	0(0)	2(18)
Inexperienced sewage treatment (3rd and later specimen)	46	34(74)	6(13)	6(13)
Water treatment	51	38(74)	7(14)	6(12)
Experienced sewage treatment	39	24(61)	10(26)	5(13)
			p = .470	
Memphis				
Inexperienced sewage treatment (1st and 2nd specimen)	10	5(50)	4(40)	1(10)
Inexperienced sewage treatment (3rd and later specimen)	38	19(50)	14(37)	5(13)
Memphis light, gas and water	53	34(64)	14(26)	5(10)
			p = .373	

TABLE 95. IMMUNOGLOBULINS (mg/dl) AMONG CONTROLS AND SEWAGE-EXPOSED WORKERS IN CINCINNATI - 1975 AND 1976

Group	No.	IgG	IgA	IgM
1975:				
Highway Maintenance	69	2857* (716)	281 (1.6)	95† (1.9)
Experienced Sewer Maintenance	41	2176* (728)	327 (1.6)	126† (1.7)
1976:				
Highway Maintenance	53	2620‡ (704)	233 (1.5)	70 (1.7)
Experienced Sewer Maintenance	33	2185‡ (707)	271§ (1.4)	68 (1.4)
Experienced Sewage Treatment	51	2496 (715)	171§ (2.5)	76 (1.8)

Figures in parentheses represent S.D. for IgG and geometric S.D. for IgA and IgM. Geometric means and S.D.s are given for IgA and IgM because calculations were done on log-transformed data.

* $p < .001$; † $p = .018$; ‡ $p = .007$; § $p = .002$ (many other differences were significant but only those for data relating to the same year are shown).

TABLE 96. IMMUNOGLOBULINS (mg/dl) - CHICAGO - JANUARY 1977

IST = Inexperienced Sewage Treatment Workers
EST = Experienced Sewage Treatment Workers
WT = Water Treatment Workers

		IgA	IgG	IgM
			p values	
Differences Among Group (Analysis of Covariance)		.426	.094	.237
Significance of Age		.332	.820	.002
Significance of Race		.221	.089	.234
			Geometric Mean Values	
	N			
IST	34	303	3327.6	85.0
EST	35	352	2921.9	89.4
WT	41	359	3261.7	79.2

TABLE 97. IMMUNOGLOBULIN LEVELS (mg/dl) AMONG CINCINNATI WORKERS - JANUARY AND OCTOBER 1978

ISE = Inexperienced Sewage-Exposed Workers
ESM = Experienced Sewer Maintenance Workers
EST = Experienced Sewage Treatment Workers
HM = Highway Maintenance Workers

	p Values			Geometric Means (mg/dl)			
	Difference Among Groups	Significance of Age	Race	ISE	ESM	HM	EST
January 1978							
IgA	.044	.222	.287	159	178	192	147
IgG	<.001	.163	.252	1737	1959	1882	1188
IgM	.305	.502	.211	82	72	68	75
October 1978							
IgA	.017	.601	.782	156	172	226	167
IgG	<.001	.578	.987	1636	1451	1451	1188
IgM	.390	.697	.815	84	84	73	74
Difference (October-January)				Mean Difference			
IgA	.001	.203	.460	-0.91	-6.90	42.70	24.35
IgG	.001	.656	.087	-100.53	-476.75	-528.46	-22.37
IgM	.161	.779	.941	4.69	27.21	5.53	-2.73
				Number of Workers			
		January 1978		36	40	46	41
		October 1978		33	41	46	41
		Workers Tested January and October		32	40	46	40

Chicago - 1978--

There were no significant differences among Chicago workers for either January or October or for the difference between the two sets of analyses (Table 98).

Memphis - 1978--

There were no significant differences among Memphis workers (Table 99).

Inexperienced Sewage-Exposed Workers--

The first and second sera collected from the inexperienced sewage-exposed workers were also analyzed. A comparison of the results of the analyses of the first and second sera (Table 100) revealed that IgG values in the inexperienced sewage treatment plant workers did not change significantly from the first sera to the second sera.

Rheumatoid Factor--

Testing for rheumatoid factor was performed on 46 wastewater-exposed and 58 highway maintenance workers in Cincinnati. Two wastewater-exposed workers, one an experienced sewer maintenance worker and the other an inexperienced sewer maintenance worker, had weakly positive latex reactions for rheumatoid factor. The frequency of positive reactions in normal populations ranges from one to five percent.

Summary--

There does not appear to be any consistent increase in immunoglobulin Ig levels among the sewage-exposed workers.

TABLE 98. IMMUNOGLOBULIN LEVELS (mg/dl) AMONG CHICAGO WORKER GROUPS - JANUARY AND OCTOBER 1978

IST = Inexperienced Sewage Treatment Plant Workers
WT = Water Treatment Plant Workers

	p Values				
	Difference Among Groups	Significance of Age	Race	Geometric Means (mg/dl) IST	WT
January 1978					
IgA	.252	.030	.001	189	191
IgG	.546	.721	<.001	1200	1200
IgM	.904	.149	.489	83	81
October 1978					
IgA	.546	.021	.024	172	179
IgG	.781	.727	.146	1119	1153
IgM	.736	.873	.232	74	72
Difference (October-January)				Mean Difference	
IgA	.390	.460	.401	1.60	-9.05
IgG	.575	.661	.160	-52.12	-27.68
IgM	.703	.145	.655	-4.28	-0.10

	Number of Workers	
January 1978	50	31
October 1978	44	30
Workers Tested both January and October 1978	43	22

TABLE 99. IMMUNOGLOBULIN LEVELS (mg/dl) AMONG MEMPHIS WORKER GROUPS - JANUARY AND OCTOBER 1978

MLGW = Memphis, Light, Gas and Water Workers
IST = Inexperienced Sewage Treatment Workers

	p Values				
	Difference Among Groups	Significance of		Geometric Means (mg/dl)	
		Age	Race	IST	MLGW
January 1978					
IgA	.119	.726	.764	174	213
IgG	.120	.521	<.001	916	1164
IgM	.641	.462	.698	91	83
October 1978					
IgA	.855	.639	.819	169	159
IgG	.709	.078	<.001	973	1164
IgM	.569	.827	.485	87	80
Difference (October-January)				Mean Difference	
IgA	.033	.915	.647	21.22	-82.30
IgG	.542	.358	.946	34.76	15.16
IgM	.646	.803	.903	13.05	0.40
				Number of Workers	
January 1978				50	53
October 1978				41	42
Workers Tested January and October 1978				41	42

TABLE 100. RESULTS OF ANALYSES FOR IMMUNOGLOBULINS IN FIRST AND SECOND SERA FOR INEXPERIENCED SEWAGE-EXPOSED WORKERS

	Mean Values								
	Cincinnati			Chicago			Memphis		
	First Sera	Second Sera	p	First Sera	Second Sera	p	First Sera	Second Sera	p
IgA	176	171	.804	196	192	.833	183	193	.668
IgG	1954	1804	.156	2461	2065	.130	1113	990	.177
IgM	83	82	.895	94	96	.854	83	110	.103
	N = 44			N = 44			N = 41		

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APPENDIX A

Family Health Diary

University of Cincinnati Medical Center

231 BETHESDA AVENUE
CINCINNATI, OHIO 45267

INFECTIOUS DISEASE DIVISION
MEDICAL SCIENCES BUILDING
ROOM 7062

FAMILY HEALTH DIARY

for

____
(name)

____
(Address)

for the Month of

______________________ 19 __________

The above person is a voluntary participant in a health study being carried out in the Departments of Environmental Health and Medicine of the University of Cincinnati with the support of the U.S. Environmental Protection Agency.

PLEASE RETURN AT THE END OF THIS MONTH, AND PICK UP A NEW DIARY FOR NEXT MONTH

APPENDIX A (continued)

Form Approved
OMB No. 158-R-0120

FAMILY HEALTH DIARY FOR PARTICIPANTS IN PUBLIC WORKS EMPLOYEES HEALTH STUDY

Please make a check mark below if any member of your household experienced any of the following conditions during the month. At the end of the month please bring the completed form to work and obtain a new form for the next month.

						Health Condition(s)								
Name	Age	Date		Did he or she miss school or work?	Was medical attention obtained? From whom?	Fever	Persistent headache	Vomiting or diarrhea, stomach or intestinal upset	Eye inflamation, or other eye trouble	Earache, or any other ear trouble	Nose or head colds, or sore throat or sinus trouble	Chest cold, shortness of breath, chest pains or persistent cough	Skin infection, rash, boils, or open sores	Other
		From	To											

If you have any questions, please call one of the study nurses: Sally Trimble, R.N. – 872-4704.
To contact Ms. Walker, R.N. or to leave a message, call 872-4689.

APPENDIX B

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO
LIST OF WASTEWATER SAMPLES AND VIROLOGICAL RESULTS

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			BGM Cultures					BGM Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
West-Southwest (Chicago)												
Secondary Effluent	2/16/77	0.625	4	3	0		0	5	5	0		0
Preliminary Effluent	6/20/77	0.669	23	18	1	E18	1.5	5	4	1	E4	1.5
Secondary Effluent	6/20/77	0.656	5	4	0		0	11	8	3	2E3 E13	4.6
Preliminary Effluent	8/9/77	0.694	3	3	0		0	2	0	0		0
Secondary Effluent	8/9/77	0.712	3	3	1	P1	1.4	3	3	0		0
Preliminary Effluent	10/12/77	0.700	6	6	2	E7 CB4	2.9	6	5	3	3E7	4.3
Secondary Effluent	10/12/77	0.725	1	1	0		0	2	2	2	2E7	2.8
Preliminary Effluent	9/26/78	0.750	0	0	0		0	0	0	0		0
Secondary Effluent	9/26/78	0.750	0	0	0		0	3	0	0		0
Calumet (Chicago)												
Preliminary Effluent	2/18/77	0.612	9	4	1	P3	1.6	3	3	0		0
Secondary Effluent	2/18/77	0.650	1	1	0		0	2	2	2	E13 E33	3.1

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			BGM Cultures					BGM Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
Preliminary Effluent	6/23/77	0.687	3	3	1	P3	1.5	7	5	0		0
Secondary Effluent	6/23/77	0.687	12	8	6	3P3 E9 E33 N.I	8.7	3	3	1	N.I	1.5
Preliminary Effluent	8/12/77	0.687	1	1	0		0	0	0	0		0
Secondary Effluent	8/12/77	0.719	1	1	0		0	2	2	2	2E7	2.8
Preliminary Effluent	10/14/77	0.712	1	1	0		0	1	1	0		0
Secondary Effluent	10/14/77	0.700	2	2	0		0	3	3	0		0
North Plant (Memphis)												
Grit Chamber	10/26/77	0.437	1	1	0		0	7	7	0		0
Secondary Effluent	10/26/77	0.265	1	1	0		0	3	3	0		0
Grit Chamber	2/24/78	0.606	0	0	0		0	6	6	0		0
Secondary Effluent	2/24/78	0.606	0	0	0		0	4	4	0		0
Grit Chamber	6/1/78	0.725	5	3	0		0	0	0	0		0
Secondary Effluent	6/1/78	0.734	0	0	0		0	1	1	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			BGM Cultures					BGM Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU/L	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
Grit Chamber	8/1/78	0.767	2	2	0		0	2	2	0		0
Maxon Plant (Memphis)												
Grit Chamber	6/1/78	0.828	3	1	0		0	1	1	0		0
Secondary Effluent	6/1/78	0.619	17	2	0		0	0	0	0		0
Grit Chamber	7/31/78	0.766	1	1	0		0	6	6	0		0
Secondary Effluent	7/31/78	0.750	0	0	0		0	0	0	0		0
Mill Creek Plant (Cincinnati)												
Preliminary Effluent	11/10/77	0.575	2	2	1	P2	1.7	9	9	0		0
Secondary Effluent	11/10/77	0.569	3	3	0		0	3	3	0		0
Preliminary Effluent	2/7/78	0.687	1	1	1	P2	1.5	3	3	0		0
Secondary Effluent	2/7/78	0.675	2	2	0		0	0	0	0		0
Preliminary Effluent	5/24/78	0.719	2	1	0		0	0	0	0		0
Secondary Effluent	5/24/78	0.719	14	6	0		0	0	0	0		0
Preliminary Effluent	8/20/78	0.750	0	0	0		0	2	2	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			BGM Cultures					BGM Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU/L	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
Secondary Effluent	8/20/78	0.750	1	1	0		0	0	0	0		0
Preliminary Effluent	10/29/78	0.688	1	1	0		0	2	2	0		0
Secondary Effluent	10/29/78	0.688	1	1	0		0	0	0	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			PMK Cultures -A+					WI-38 Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
West-Southwest (Chicago)												
Secondary Effluent	2/16/77	0.625	0	0	0		0	0	0	0		0
Preliminary Effluent	6/20/77	0.669	0	0	0		0	2	1	0		0
Secondary Effluent	6/20/77	0.656	0	0	0		0	0	0	0		0
Preliminary Effluent	8/9/77	0.694	0	0	0		0	0	0	0		0
Secondary Effluent	8/9/77	0.712	1	1	0		0	6	6	0		0

*Represents sample volume before concentration
+Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			PMK Cultures -A+					WI-38 Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
Preliminary Effluent	10/12/77	0.700	1	1	1	E1	1.4	0	0	0		0
Secondary Effluent	10/12/77	0.725	0	0	0		0	2	2	0		0
Preliminary Effluent	9/26/78	0.750	0	0	0		0	0	0	0		0
Secondary Effluent	9/26/78	0.750	0	0	0		0	0	0	0		0
Calumet (Chicago)												
Preliminary Effluent	2/18/77	0.612	0	0	0		0	1	1	0		0
Secondary Effluent	2/18/77	0.650	0	0	0		0	1	1	0		0
Preliminary Effluent	6/23/77	0.687	0	0	0		0	1	1	0		0
Secondary Effluent	6/23/77	0.687	0	0	0		0	2	2	0		0
Preliminary Effluent	8/12/77	0.687	0	0	0		0	0	0	0		0
Secondary Effluent	8/12/77	0.719	0	0	0		0	2	2	0		0
Preliminary Effluent	10/14/77	0.712	0	0	0		0	0	0	0		0
Secondary Effluent	10/14/77	0.700	0	0	0		0	10	6	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			PMK Cultures-A+					WI-38 Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
North Plant (Memphis)												
Grit Chamber	10/26/77	0.437	0	0	0		0	1	1	0		0
Secondary Effluent	10/26/77	0.265	0	0	0		0	0	0	0		0
Grit Chamber	2/24/78	0.606	0	0	0		0	0	0	0		0
Secondary Effluent	2/24/78	0.606	0	0	0		0	0	0	0		0
Grit Chamber	6/1.78	0.725	0	0	0		0	9	9	4	E2 E6 E33 N.I.	5.5
Secondary Effluent	6/1/78	0.734	0	0	0		0	1	1	1	E2	1.4
Grit Chamber	8/1/78	0.767	0	0	0		0	0	0	0		0
Maxon Plant (Memphis)												
Grit Chamber	6/1/78	0.828	0	0	0		0	2	2	2	E3 E6	2.4
Secondary Effluent	6/1/78	0.619	0	0	0		0	0	0	0		0
Grit Chamber	7/31/78	0.766	0	0	0		0	0	0	0		0
Secondary Effluent	7/31/78	0.750	0	0	0		0	0	0	0		0
Mill Creek Plant (Cincinnati)												
Preliminary Effluent	11/10/77	0.575	0	0	0		0	0	0	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX B (continued)

Sample Description	Collection Date	Sample Volume Assayed in Each Cell System (L)*	Plaque Data									
			PMK Cultures -A+					WI-38 Cultures-A+				
			Total PFU	#Plaques Picked	Conf. PFU/L	Virus Identity	Conf. PFU/L	Total PFU	#Plaques Picked	Conf. PFU	Virus Identity	Conf. PFU/L
Secondary Effluent	11/10/77	0.569	0	0	0		0	5	5	0		0
Preliminary Effluent	2/7/78	0.687	0	0	0		0	0	0	0		0
Secondary Effluent	2/7/78	0.675	0	0	0		0	0	0	0		0
Preliminary Effluent	5/24/78	0.719	0	0	0		0	0	0	0		0
Secondary Effluent	5/24/78	0.719	0	0	0		0	4	2	0		0
Preliminary Effluent	8/20/78	0.750	0	0	0		0	0	0	0		0
Secondary Effluent	8/20/78	0.750	0	0	0		0	0	0	0		0
Preliminary Effluent	10/29/78	0.688	0	0	0		0	0	0	0		0
Secondary Effluent	10/29/78	0.688	0	0	0		0	0	0	0		0

* Represents sample volume before concentration
+ Inoculum neutralized with poliovirus 1, 2 and 3 antisera
P = Poliovirus
C = Coxsackievirus
E = Echovirus

APPENDIX C

SIGNIFICANCE LEVELS (P-VALUES) FOR INITIAL VIRUS SEROLOGY SURVEY STATISTICAL COMPARISONS: CINCINNATI

	Dates of Sera Collected			Titer Level Changes	
Virus	7/76	1/77	10/77	7/76 - 1/77	1/77 -10/77
Polio 1	.211	.261	.940	.376	.725
Polio 2	.043	.003	.342	.678	.562
Polio 3	.754	.990	.999	.420	.525
Coxsackie A7	.453	.428	.891	.204	.575
Coxsackie A9	.287	.234	.617	.280	.855
Coxsackie A16	.352	.659	.384	.386	.385
Coxsackie A21	.153	.213	.286	.485	.313
Coxsackie B1	.648	.348	.471	.664	.853
Coxsackie B2	.775	.554	.864	.852	.063
Coxsackie B3	.653	.170	.402	.625	.342
Coxsackie B4	.645	.213	.251	.502	.640
Coxsackie B5	.685	.599	.380	.316	.080
Coxsackie B6	.192	.226	.428	.424	.147
Echo 1	.149	.018	.066	.702	.255
Echo 2	.718	.740	.878	.432	.431
Echo 3	.686	.691	.982	.552	.191
Echo 4	.408	.251	.533	.613	.613

(continued)

APPENDIX C (continued)

Virus	Dates of Sera Collected 7/76	1/77	10/77	Titer Level Changes 7/76 - 1/77	1/77 - 10/77
Echo 6	.258	.374	.074	.065	.006
Echo 8	.023	.188	.280	.823	.116
Echo 9	.501	.469	.060	.765	.841
Echo 11	.919	.468	.734	.377	.407
Echo 13	.478	.634	.725	.873	.257
Echo 14	.240	.407	.481	.105	.461
Echo 19	.108	.134	.341	.173	.186
Echo 24	.461	.578	.133	.324	.320
Echo 25	.960	.694	.335	.445	.902
Echo 30	.314	.399	.735	.711	.763
Adenovirus	.082	.296	.915	.625	.003
Reovirus	.351	.333	.327	.422	.419
HSV	.061	.001	.021	.294	.371
CMV	.265	.318	.147	.443	.411

APPENDIX D

SIGNIFICANCE LEVELS (P-VALUES) FOR INITIAL VIRUS SEROLOGY SURVEY STATISTICAL COMPARISONS: CHICAGO

	Dates of Sera Collected			Titer Level Changes	
Virus	7/76	1/77	10/77	7/76 - 1/77	1/77 -10/77
Polio 1	.648	.265	.129	.610	.911
Polio 2	.257	.769	.416	.278	.712
Polio 3	.590	.393	.353	.173	.239
Coxsackie A7	.103	.177	.534	.322	.996
Coxsackie A9	.383	.097	.328	.571	.725
Coxsackie A16	.788	.390	.475	.062	.152
Coxsackie A21	.744	.125	.740	.201	.150
Coxsackie B1	.289	.490	.232	.641	.398
Coxsackie B2	.199	.644	.293	.288	.635
Coxsackie B3	.045	.093	.250	.686	.557
Coxsackie B4	.166	.525	.720	.718	.602
Coxsackie B5	.197	.739	.537	.443	.384
Coxsackie B6	.738	.751	.762	.895	.473
Echo 1	.561	.635	.536	.074	.263
Echo 2	.287	.426	.905	.476	.263
Echo 3	.627	.693	.366	.763	.375
Echo 4	.561	.920	.918	.046	.464
Echo 6	.083	.008	.453	.893	.198

(continued)

APPENDIX D (continued)

Virus	Dates of Sera Collected			Titer Level Changes	
	7/76	1/77	10/77	7/76 - 1/77	1/77 -10/77
Echo 8	.283	.070	.048	.256	.340
Echo 9	.084	.378	.573	.231	.444
Echo 11	.231	.169	.791	.639	.645
Echo 13	.167	.650	.904	.209	.694
Echo 14	.311	.806	.674	.321	.363
Echo 19	.460	.759	.400	.176	.624
Echo 24	.986	.390	.421	*	*
Echo 25	.181	.260	.065	.153	.059
Echo 30	.201	.195	.081	.222	.652
Adenovirus	.256	.214	.081	.815	.612
Reovirus	.902	.610	.316	.871	.179
HSV	.515	.185	.046	.360	.105
CMV	.962	.431	.799	.586	.291

*No titer levels changed.

APPENDIX E

SIGNIFICANCE LEVELS (P-VALUES) FOR SECOND PHASE OF VIRUS SEROLOGY STATISTICAL COMPARISONS: CINCINNATI

	Date of Sera Collection		Titer Level Changes
Virus	Jan., 1978	Oct., 1978	Jan. - Oct., 1978
Polio 1	.476	.451	.455
Polio 2	.169	.156	.451
Polio 3	.641	.398	.419
Coxsackie A9	.083	.325	.035
Coxsackie B1	.707	.734	.604
Coxsackie B2	.595	.240	.911
Coxsackie B3	.247	.884	.534
Coxsackie B4	.710	.680	.368
Coxsackie B5	.511	.266	.784
Echo 3	.223	.054	.112
Echo 6	.090	.085	.098
Echo 8	.099	.381	.750
Echo 9	.051	.297	.330
Echo 11	.590	.033	.743
Echo 21	.277	.633	.445
Adenovirus	.041	.925	.567
HSV	.008	.009	.289

APPENDIX F

SIGNIFICANCE LEVELS (P-VALUES) FOR SECOND PHASE OF VIRUS SEROLOGY SURVEY STATISTICAL COMPARISONS: CHICAGO

	Date of Sera Collection		Titer Level Changes
Virus	Jan., 1978	Oct., 1978	Jan. - Oct., 1978
Polio 1	.084	.971	.205
Polio 2	.678	.670	.847
Polio 3	.898	.315	.283
Coxsackie A9	.337	.453	.597
Coxsackie B1	.352	.404	.680
Coxsackie B2	.757	.491	.354
Coxsackie B3	.513	.729	.344
Coxsackie B4	.530	.707	.435
Coxsackie B5	.208	.749	.863
Echo 3	.205	.830	.728
Echo 6	.402	.141	.368
Echo 8	.117	.094	.481
Echo 9	.523	.602	.537
Echo 11	.036	.365	.446
Echo 21	.268	.194	.178
Adenovirus	.588	.441	.542
HSV	.233	.894	.488

APPENDIX G

SIGNIFICANCE LEVELS (P-VALUES) FOR SECOND PHASE OF VIRUS SEROLOGY SURVEY STATISTICAL COMPARISON: MEMPHIS

	Date of Sera Collection		Titer Level Changes
Virus	Jan., 1978	Oct., 1978	Jan. - Oct., 1978
Polio 1	.554	.956	.864
Polio 2	.100	.480	.288
Polio 3	.478	.335	.806
Coxsackie A9	.012	.002	.080
Coxsackie B1	.522	.962	.421
Coxsackie B2	.187	.306	.561
Coxsackie B3	.534	.780	.953
Coxsackie B4	.838	.482	.299
Coxsackie B5	.725	.952	.065
Echo 3	.803	.686	.402
Echo 6	.593	.791	.488
Echo 8	.625	281	.653
Echo 9	.425	.986	.671
Echo 11	.391	.621	.204
Echo 21	.193	.429	.358
Adenovirus	.435	.081	.703
HSV	.883	.643	.252

APPENDIX H

COMPARISON OF FINAL VIRUS SEROLOGY DATA BETWEEN COMBINED THREE-CITY INEXPERIENCED SEWAGE-EXPOSED AND CONTROL GROUPS*

	p Values		
	Prevalence		
Virus	January 1978	October 1978	Titer level changes
Polio 1	.141	.720	.203
Polio 2	.276	.730	.046
Polio 3	.658	.873	.688
Coxsackie A9	.085	.003	.076
Coxsackie B1	.302	.406	.429
Coxsackie B2	.282	.171	.659
Coxsackie B3	.658	.464	.770
Coxsackie B4	.289	.131	.196
Coxsackie B5	.719	.545	.386
Echo 3	.731	.116	.496
Echo 6	.122	.094	.285
Echo 8	.040	.151	.335
Echo 9	.479	.602	.439
Echo 11	.433	.379	.333
Echo 21	.248	.196	.247
Adenovirus	.336	.048	.360
Herpes Simplex	.008	.035	.307

*There were 119 workers in the inexperienced sewage-exposed group and 116 in the control group.

APPENDIX I

SECOND PHASE OF VIRUS SEROLOGY SURVEY - INEXPERIENCED WORKERS: COMPARISON OF TITER LEVEL CHANGES FIRST SERA TO JANUARY 1978 SERA

(A) CITY-BY-CITY

Virus	Cincinnati		Chicago		Memphis	
	N*	p	N*	p	N*	p
Polio 1	29	.613	42	.810	41	.764
Polio 2	29	.968	44	.990	41	.600
Polio 3	29	.549	44	.960	41	.893
Coxsackie A9	29	.692	43	.682	41	.863
Coxsackie B1	29	.850	45	.755	41	.511
Coxsackie B2	29	.455	45	.461	41	.446
Coxsackie B3	29	.899	43	.702	41	.366
Coxsackie B4	29	.968	45	.338	41	.733
Coxsackie B5	29	.410	45	.867	41	.829
Echo 3	29	.130	45	.785	41	.038
Echo 6	29	.510	45	.318	41	.409
Echo 9	29	.529	45	.984	41	.764
Echo 11	29	.712	45	.809	41	.918
Echo 21	29	.629	44	.876	41	.570
Adenovirus	29	.956	45	.637	41	.905
Herpes Simplex	29	.801	44	.764	40	.853
Echo 8	29	.999	45	.490	38	.947

(continued)

APPENDIX I (continued)

(B) BETWEEN CITIES

Virus	p	Number of Workers Cincinnati	Chicago	Memphis
Polio 1	.810	29	42	41
Polio 2	.903	29	44	41
Polio 3	.599	29	44	41
Coxsackie A9	.222	29	43	41
Coxsackie B1	.202	29	45	41
Coxsackie B2	.264	29	45	41
Coxsackie B3	.204	29	43	40
Coxsackie B4	.900	29	45	40
Coxsackie B5	.499	29	45	41
Echo 3	.517	29	45	41
Echo 6	.885	28	44	41
Echo 9	.554	29	45	41
Echo 11	.340	28	45	41
Echo 21	.640	29	44	41
Adenovirus	.347	29	45	41
Herpes Simplex	.067	29	43	39
Echo 8	.691	29	45	38

*Number of workers.

APPENDIX J

LENGTH OF TIME ON THE JOB: EFFECT ON VIRUS SEROLOGY PREVALENCE (≥ 2) FINAL VIRUS SEROLOGY - CINCINNATI

Virus	Experienced sewage treatment	Experienced sewer maintenance
Polio 1	.002	.198
Polio 2	.958	.029
Polio 3	.060	.021
Coxsackie A9	.162	.565
Coxsackie B1	.899	.730
Coxsackie B2	.299	.898
Coxsackie B3	.993	.046
Coxsackie B4	.595	.527
Coxsackie B5	.276	.193
Echo 3	.750	.400
Echo 6	.254	.795
Echo 8	.015	.604
Echo 9	.300	.668
Echo 11	.828	.516
Echo 21	.098	.656
Adenovirus	.621	.331
Herpes Simplex	.535	.939

By ANOVA